

**No. 23-15285**

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**IN THE UNITED STATES COURT OF APPEALS  
FOR THE NINTH CIRCUIT**

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**IN RE GOOGLE PLAY STORE ANTITRUST LITIGATION**

MARY CARR, ET AL.  
V.  
GOOGLE LLC, ET AL.

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Interlocutory Appeal from the  
U.S. District Court for the Northern District of California  
No. 21-md-2981; No. 20-cv-5761  
Hon. District Judge James Donato

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**BRIEF FOR PLAINTIFFS-APPELLEES  
[Public Redacted]**

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## INTRODUCTION

Google's Android operating system runs over 70 percent of all smartphones worldwide, and virtually all non-Apple smartphones. Essential to all smartphones are downloadable software applications ("apps"), which third-party developers create. Some developers charge consumers money to download their apps, while other developers list their apps for free but offer in-app digital purchases for items such as premium content and video game enhancements.

Through a web of contractual and technical barriers to competition, Google has for many years leveraged its control over the Android operating system to maintain its Google Play Store as the only viable marketplace for Android apps. Google Play controls over 90 percent of the Android app download market, generating over [REDACTED] in 2021 for Google at margins exceeding [REDACTED].

Google's monopoly has enabled it to charge a supra-competitive 30 percent commission not only on nearly all apps sold through the Google Play Store, but also on every subsequent in-app purchase made in those apps. This excessive 30 percent commission (in economic terms, the "take rate") causes consumers to pay more for apps and in-app content than

developers would charge in a competitive market. In this antitrust litigation, a class of consumers who bought apps and in-app purchases from the Google Play Store seek to recover damages flowing from Google's anticompetitive conduct.

Plaintiffs have demonstrated on a class-wide basis, using common proof, that by raising developers' costs Google's supra-competitive commissions have raised the prices consumers pay for apps and in-app purchases. Employing accepted and reliable economic methods, Plaintiffs' expert has shown that: (1) in a competitive market with other viable app stores, Google would have significantly lowered the 30 percent commission it extracts from developers; and (2) developers with lower costs would have charged consumers lower prices. These conclusions are consistent with fundamental principles of economics, including that rational market participants respond to reduced costs by lowering prices to increase demand and profits.

After extensive briefing and a live proceeding with testimony from both parties' experts, the District Court certified the consumer class. The District Court found that Plaintiffs' expert used well-established economic models, noting that even Google's expert recognized these

models were not “junk science.” The District Court also credited the significant empirical work Plaintiffs’ expert performed to verify the fit of his models with real-world data. Importantly, the District Court carefully considered and rejected Google’s expert’s theory that increased developer prices did not lead to increased consumer costs, finding that Google’s expert’s analysis was of “minimal” probative value because the expert proceeding revealed “serious questions” about issues endemic to her analysis. 1-ER-23; 2-ER-113. Finally, the District Court considered and rejected a “blunderbuss of objections” Google asserted with little or no empirical evidence in support of its position that individualized issues would predominate over common ones. 1-ER-20.

Instead of making a frontal *Daubert* challenge or addressing the deficiencies in its expert proof, Google contends on appeal that its anticompetitive conduct did not injure most consumers and that class certification is inappropriate because individualized injury issues predominate. In doing so, Google effectively asks this Court to treat its expert analysis as undisputed fact, and to disregard the District Court’s resolution of disputed issues, relying on a misstatement of the standard of review and gross mischaracterizations of the District Court’s analysis.

This Court should reject Google’s invitation to upset the District Court’s well-considered weighing of the evidence.

As explained more fully below, Google exaggerates and mischaracterizes its evidence of uninjured class members, which the District Court found to be so infirm as to be “of minimal value.” 1-ER-23. To rebut Plaintiffs’ expert analysis of common impact on class members, Google’s expert considered only a tiny, unrepresentative set of data for a window of time too short to expect broad price changes. Google’s expert also considered only whether prices were reduced for specific SKUs (which are designations that developers assign to items that they sell) rather than for apps or in-app products. This analysis is flawed because developers can and do reduce prices by changing SKUs or introducing new SKUs for the same products. Because of these problems in its expert analysis, Google did not reliably identify a single uninjured class member, let alone a great number of them. Google suggests that the District Court ignored its evidence, but Plaintiffs’ expert testified at length about these flaws in Google’s proof during the expert proceeding, and the District Court specifically cited that testimony in support of its

finding that Google’s expert opinions were fraught with “serious questions” that were endemic to Google’s analysis. 1-ER-23; 2-ER-113.

Even were Google’s evidence of uninjured class members reliable, this Court has already held that the potential inclusion of uninjured members in a class does not necessarily preclude certification. *Olean Wholesale Grocery Coop., Inc. v. Bumble Bee Foods LLC*, 31 F.4th 651, 669 (9th Cir. 2022) (en banc). And if needed, the District Court can later narrow the class. *Id.* n.14.

Google also argues that the District Court failed to conduct a rigorous Rule 23 analysis. Not so. The District Court carefully evaluated the competing expert testimony at an evidentiary hearing. Rather than ignoring Google’s arguments, the District Court correctly found those arguments—and the expert testimony on which they are based—to be “unfounded” and of “negligible” persuasive value. 1-ER-21-23. These factual findings are supported by substantial evidence and are thus entitled to deference on appeal. Google offers this Court no proper basis to overturn them.

In its efforts to attack the District Court’s rigorous analysis, Google re-raises a handful of the scattershot arguments it made in passing in

the District Court, suggesting the District Court paid them insufficient attention. Google argues at length that consumers were uninjured because developers use “focal point” pricing ending in \$0.99. But the foundation Google offered for this argument was both disputed and infirm. Focal point pricing does not mean retailers blindly price in 99-cent increments, and Plaintiffs demonstrated that developers would lower prices in 10-cent increments. Moreover, Google ignores that it imposed the \$0.99 minimum price in its app store that it now relies on to say that developers would not lower prices below 99 cents. Google cannot benefit from its own anticompetitive conduct to maintain that its victims were “uninjured.” *See Apple v. Pepper*, 139 S. Ct. 1514, 1523 (2019) (rejecting theory that “would provide a roadmap for monopolistic retailers to structure transactions with manufacturers or suppliers so as to evade antitrust claims by consumers and thereby thwart effective antitrust enforcement”).

Google also asserts that Plaintiffs’ expert erred by using Google’s own app categories—which Google created and uses for its own internal business analysis—in constructing his model. Google pokes fun at examples of imperfect substitutes within the same category, but the

District Court rightly credited Plaintiffs' expert's empirical analysis of the overall fit of these categories over Google's cherry-picked, anecdotal examples, finding that use of Google's categories "is reasonable in light of the evidence." 1-ER-22. That finding, along with the District Court's many other findings, amply supports the District Court's class certification order.

Finally, in a last-ditch effort to manufacture error, Google argues that the District Court erred by noting, in addition to its finding that damages could be proved with common evidence, that "the presence of individualized damages cannot, by itself, defeat class certification under Rule 23(b)(3)." *Leyva v. Medline Indus. Inc.*, 716 F.3d 510, 514 (9th Cir. 2013). That is an accurate statement of Ninth Circuit law. In any event, the District Court expressly found that Plaintiffs demonstrated that they can reliably prove damages for each plaintiff using common methods. That is all the law requires. Individual damage questions (if any) would not predominate at trial, and the district court properly held that they do not prevent class certification.

In the end, Google "improperly conflates the question whether evidence is capable of proving an issue on a class-wide basis with the

question whether the evidence is persuasive.” *Olean*, 31 F.4th at 679. Google remains free to attack Plaintiffs’ economic evidence on the merits. Because Plaintiffs’ expert demonstrated that well-accepted economic models are capable of proving injury and damages on a class-wide basis, the District Court rightly certified the class.

### **STATEMENT OF JURISDICTION**

Plaintiffs concur with Google’s jurisdictional statement.

### **STATEMENT OF ISSUES FOR REVIEW**

Did the District Court abuse its discretion in certifying the class after conducting a rigorous analysis of the parties’ competing expert evidence and determining that common questions would predominate over any individualized issues?

### **FEDERAL RULE OF CIVIL PROCEDURE 23**

Federal Rule of Civil Procedure 23(b) provides, in relevant part:

A class action may be maintained if Rule 23(a) is satisfied and if: . . . (3) the court finds that the questions of law or fact common to class members predominate over any questions affecting only individual members . . . .

## **STATEMENT OF THE CASE**

### **I. STATEMENT OF FACTS**

#### **A. Google’s Android App Distribution Monopoly Reaps Supra-Competitive Profits From Consumers**

Google’s Android operating system and Apple’s iOS operating system collectively control over 99 percent of the market for mobile operating systems. 3-SER-456. Apple does not license its operating system to third-party manufacturers, reserving it exclusively for Apple devices. 3-SER-455. As a result, virtually every non-Apple smartphone (whether made by Samsung or another manufacturer) and over 70 percent of all smartphones use Google’s Android operating system. 3-SER-456, 459-461.

Google has leveraged its power over the Android operating system to make the Google Play Store the only viable marketplace for Android apps and in-app purchases. For many years, Google deterred wireless carriers from launching app stores of their own by offering them much of the revenue the Play Store generated on the smartphones they sold, all with the secret intent to “change the rules” and eliminate this revenue sharing once the Play Store secured dominance, as it eventually did. 1-SER-56; 3-SER-470-475. In addition, as a condition to licensing software

critical to Android, Google requires manufacturers to preload phones they sell with the Google Play Store in a prominent position on the home screen. 3-SER-476-478. Google also programmed the Android operating system to interpose technical barriers and misleading warnings to prevent consumers from downloading apps and app stores from other sources. To install Amazon’s app store, for example, a consumer must navigate 19 steps, including a warning falsely suggesting that the download is from an “unknown source” that may harm the device and put consumers’ personal information at risk.<sup>1</sup> 3-SER-381-386. Google also pressured would-be competitors “not to create their own app stores.” 3-SER-377; *see also* 3-SER-368-373. As a result of this and other improper conduct, Google illegally created and maintained a stranglehold over the distribution of apps and in-app content on Android mobile devices, with a market share exceeding 90 percent. 3-SER-466-67.

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<sup>1</sup> Certain *amici* argue that Google’s conduct in the market is pro-competitive. ECF 28 at 15-22; ECF 33 at 9-17. Those arguments were not presented to the District Court and do not affect class certification: “Rule 23 grants courts no license to engage in free-ranging merits inquiries at the certification stage.” *Amgen Inc. v. Conn. Ret. Plans & Tr. Funds*, 568 U.S. 455, 466 (2013). *Amici* have not even seen the discovery in this case documenting Google’s far-ranging and calculated anticompetitive acts, including evidence of direct collusion with potential competitors.

Google further leveraged its power in app distribution to funnel sales of digital in-app content through its Google Play Billing payment system. When developers offer in-app purchases of digital content, Google requires that they use Google Play Billing and pay Google its “take rate” forever, no matter how long ago the app was downloaded, or how long the developer has had a relationship with the consumer. 3-SER-482. As a condition to offering apps on the Play Store, Google prohibits developers from steering their customers to lower-priced app stores or websites to buy apps and in-app content. *Id.* Google’s web of anticompetitive restrictions ensures that it continues to collect its supra-competitive toll on almost all transactions involving Android apps. 3-SER-479-482.

There is “[n]o rationale” for Google’s 30% take rate, [REDACTED]

[REDACTED] 3-SER-363; 3-SER-357. Nor is there any significant variation or meaningful individual negotiation. Google’s take rate is largely uniform, as 92.4 percent of transactions during the class period were at the 30 percent rate. 1-ER-11; 2-ER-99. Google has offered lower rates to small sets of developers. 3-SER-404-06. [REDACTED]

[REDACTED]

[REDACTED] 3-SER-390. As a result, Google has reaped [REDACTED] in excess monopoly profits each year. 3-SER-463. In 2021 alone, its profits from sales and advertising on Google Play totaled more than [REDACTED] 3-SER-463 & nn.124-25.

Developers set the prices for their apps and in-app products. Their biggest cost is generally Google’s “service fee.” Google argues that developers do not consider this cost when pricing apps and in-app transactions because of focal point pricing, but significant record evidence undermines that assertion. Pricing data from the Play Store shows “prices at regular, ten-cent intervals.” 5-ER-706-07. More than 20 percent of the top paid apps and over 130 million transactions have prices that do not end in “99.” 5-ER-704-05. Indeed, economic evidence confirms that focal point pricing for low-priced goods often involves 10-cent, rather than dollar, pricing intervals, and Google in 2022 lowered its minimum price from \$0.99 to \$0.05. 5-ER-706 & n.58.

Consumers directly pay Google’s service fee on transactions made through the Play Store. 1-ER-18-19; *cf. Apple*, 139 S. Ct. at 1525 (“The

overcharge has not been passed on by anyone to anyone.”). Consumers thus bear the brunt of Google’s overcharge, as Google deducts its service fee from each consumer’s payment before forwarding the remainder to developers. 1-ER-18.

### **B. Dr. Singer’s Common Analysis Of Injury And Damages**

The Google Play Store has a monopoly in two types of markets. First, there is the app distribution market, in which the Play Store connects developers with consumers. 2-ER-46-48. Consumers want more applications from which to choose, and developers want more customers, so each benefits as the numbers of the other increase (which economists call “indirect network effects”). 2-ER-47-48. Because of these indirect network effects, the app distribution market is “two-sided.” *Id.* Second, there is a market for in-app purchases of digital content. This market is one-sided because once a consumer purchases an app, the matchmaking function is complete and developers and consumers no longer benefit from indirect network effects. 2-ER-79. If not for Google’s anticompetitive tie requiring developers to use Google Play Billing for all in-app purchases of digital content as a condition for selling their apps

on the Play Store, developers could deal directly with consumers without Google as a middleman. *See id.*

Plaintiffs' economist, Dr. Hal Singer, examined whether Google's actions harmed consumers. Google does not question Dr. Singer's credentials, "and for good reason." 1-ER-10. Dr. Singer is a managing director at Econ One, received his Ph.D. at Johns Hopkins, taught at Georgetown University, has published in antitrust journals, and has testified before Congress on competition issues. *Id.* Dr. Singer's analysis proceeded in two basic steps. He first considered whether Google would lower its 30% take rate if faced with competition. He then analyzed whether those lower take rates would reduce consumer prices both for initial app purchases (the two-sided market) and subsequent in-app purchases (the one-sided market). This reduction in consumer prices is called "pass through" because it measures the extent to which a developer would pass through its own cost savings to consumers.

**Determining the Competitive Service Fee.** Because the economics of the two-sided market for apps and the one-sided market for in-app purchases differ, Dr. Singer uses distinct models for each. In both

cases, Dr. Singer used standard tools from the economist’s toolbox, not the sort of jury-rigged invented science that is the concern of *Daubert*.

To examine the two-sided apps market, Dr. Singer used the Rochet-Tirole model, “the foundational model of pricing in a two-sided market.”<sup>2</sup> 2-ER-48. The model used inputs from Google’s own data, plus an average pass-through rate that Dr. Singer calculated from a third model. *Id.*; 5-ER-731. Using Rochet-Tirole, Dr. Singer calculated that Google’s take rate for apps would fall from an average of 30.1 percent to 23.4 percent had the market for app distribution been competitive.<sup>3</sup> 5-ER-731; 5-ER-729; 1-ER-20.

To determine what would happen in the one-sided market for in-app purchases, Dr. Singer used the Landes-Posner model, a “common and classic” model for one-sided markets to determine “how a dominant firm changes its prices in response to entry.”<sup>4</sup> 2-ER-79-80. Using Landes-

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<sup>2</sup> Google’s economist, Dr. Burtis, conceded that Rochet-Tirole model “is used in economic literature.” 2-ER-54-55.

<sup>3</sup> Amicus ICLE argues that Dr. Singer did not account for non-price effects in two-sided markets. ECF 48 at 19-23. To the extent that non-price effects were presented to the District Court, it rightly rejected them as speculative. 1-ER-25.

<sup>4</sup> When asked about the Landes-Posner model, Google’s expert agreed that “economists use . . . these kinds of equations” and that it is not “junk science.” 2-ER-83-84.

Posner, Dr. Singer calculated that Google's take rate for in-app purchases would fall from an average of 29.2 percent to 14.8 percent had the market been competitive. 5-ER-744; 1-ER-20.

**Calculating Pass-Through of Google's Service Fee.** After establishing that Google would have lowered its take rate in a competitive market, Dr. Singer considered whether and to what extent consumers would have paid less but for Google's supra-competitive take rate.

It is a fundamental principle of economics that a firm's costs affect its prices. 5-ER-748-49. To quantify the effect, economists use demand curves to determine the change in price that would maximize a firm's profits in response to a change in costs. 5-ER-749. Before choosing a demand model to apply, Dr. Singer tested three models—linear, constant elasticity, and logit—with a regression analysis to find the model best suited to the task. 1-SER-6-8.

When performing the regression analysis, Dr. Singer used Google's app categories to define the field of competition. The Google Play Store offers categories into which developers sort their apps, such as "games" or "comics." 5-ER-711-13. Dr. Singer relied on significant evidence that

the categories “reflect economically reasonable groupings of consumer tastes.” 5-ER-711. Google tells developers that “[c]ategories and tags help users to search for and discover the most relevant apps in the Play Store.” *Id.* Google also uses the app categories for many of its own analyses of consumer spending patterns. 3-SER-315-23; *see also* 5-ER-711 (compiling such analyses).

Dr. Singer’s regression analyses demonstrated that the logit model accurately predicted how price changes affect consumer demand to the highest levels of statistical significance in each of the app categories (save one limited-time category that Google phased out). 5-ER-750-53; 2-ER-120-21; 1-SER-6-8; 3-SER-492-95. That finding gave Dr. Singer confidence that the logit model was suitable to model pass-through in this case. 2-ER-121.

Economic literature and antitrust practice support using logit to calculate cost pass-through. Logit is a widely used economic model. The Department of Justice 1992 Horizontal Merger Guidelines “use it as the base case for the analysis of mergers in differentiated products industries.” 1-SER-26. It is also “commonly employed in antitrust analysis of mergers involving differentiated products.” 1-SER-47; *see*

also Frank Verboven & Theon Van Dijk, *Cartel Damages Claims and the Passing-On Defense*, 57 J. Indus. Econ. 457, 473-75 (2009) (calculating pass-through of overcharges from a European vitamin cartel).

The logit model is premised on the bedrock economic principle that firms set prices to maximize profit. 5-ER-709-10. From that starting point, the logit demand model predicts how rational firms change their prices in response to changes in their marginal costs to maximize profit.

*Id.*

The logit model predicts that firms with a higher share of the market (reflecting a stronger market position and pricing power) will adjust prices less in response to cost changes than those with a lower share of the market (reflecting less pricing power). 5-ER-710. The result is that the percentage of a cost-reduction a developer will pass through on an app is inversely proportional to the app's share of the market. *Id.*; 5-ER-752-53. This principle, which Google calls the “one-minus share formula,” is peer-reviewed and well accepted in economic analysis. See Nathan Miller, Marc Remer, & Gloria Sheu, *Using cost pass-through to calibrate demand*, 118 Econ. Letters 451, 452 (2013) (1-SER-46-47).

Dr. Singer used these models to calculate, for each app sold through the Play Store, the extent to which a lower take rate by Google would have resulted in lower prices to consumers in the but-for world. 5-ER-752-53. Using this app-by-app data, he then calculated category-level and market-level average pass-through rates. 5-ER-754. Because the level of competition varies for different categories of apps, the logit model predicts pass-through rates for each category of app. Pass-through rates ranged from 25% (for Beauty, a highly concentrated category), to 96% (for Tools, a category with more intense competition). 5-ER-765-66.

**Calculating Injury and Damages.** Dr. Singer calculated individualized injury and damages using the Rochet-Tirole model (for app purchases) and Landes-Posner model (for in-app purchases) to determine the reduced take rate, and the logit model to determine how much consumer prices would drop as a result of the take-rate reduction. For each app category, Dr. Singer calculated consumer damages using the actual take rate from Google's data, the expected but-for take rate as calculated by the Rochet-Tirole and Landes-Posner models, and the pass-through rate calculated by the logit demand model. 5-ER-765-66. These same methods can be applied on an app-by-app level rather than the

category level. 5-ER-763 n.592; 2-ER-125. These methods can be formulaically applied to every class member to determine individual damages, 2-ER-123-25, and can be adjusted to account for focal point pricing intervals. 5-ER-705-07; 1-ER-22.

### **C. Dr. Burtis' Flawed Pass-Through Analysis**

Google's expert, Dr. Michelle Burtis, analyzed specific SKUs (which, again, are designations that developers assign to items that they sell) to determine what happened to prices following three instances in which Google reduced its take rate for certain limited sets of transactions. 2-ER-268. Those transactions in total covered SKUs responsible for only 11% of consumer spending in the Play Store. 3-SER-399. Specifically, they included:

1. SKUs from certain developers who received lower service fees through participation in specialized Google programs for limited categories of apps like music and video streaming apps. 2-ER-268.
2. SKUs from Google's 2018 service fee reduction for users who maintain a subscription product for more than one year. *Id.*

3. SKUs from Google's small developer program, which starting in July 2021 reduced the service fee for the first \$1 million of a developer's annual revenue. *Id.*

Dr. Burtis' reliance on these three limited events was fundamentally flawed. For example, the 2018 price reduction on subscriptions took effect only for users who subscribed continuously for more than one year, while prices remained at 30% for new users. 3-SER-423-24. But developers could not feasibly lower the price for subscribers subject to the new 15 percent take rate without also lowering prices for subscribers still subject to the 30 percent take rate. 3-SER-424-25.

[REDACTED] 3-SER-309. This prevented developers from passing through their cost savings.

Dr. Burtis' other analyses suffer from similarly systemic flaws, including those stemming from her narrow focus on individual SKUs rather than on apps and in-app products (which may have multiple SKUs). 2-ER-110-14; 3-SER-425-32. By focusing solely on individual SKUs rather than the products at issue, Dr. Burtis' analysis could not determine whether a developer changed a price by introducing another

SKU or shifting purchases to another SKU for the same product. Consumers buy products, not SKUs.

This error affected the primary example Dr. Burtis offered at the expert proceeding. Dr. Burtis claimed that iHeart Radio did not change its price after receiving a reduction in Google's take rate. In reality, however, when iHeart Radio received a take-rate reduction, it reduced its prices by selling the same product under a different SKU with a lower price. 2-ER-109-14. While Google and Dr. Burtis tried to use iHeart Radio as "real world data" contradicting Dr. Singer's pass-through models, it did precisely the opposite, demonstrating that real-world examples confirmed his analysis.

This error was not limited to iHeart Radio. 2-ER-113. Tinder has three major subscription products—Plus, Gold, and Platinum, but offers over 512 SKUs. 3-SER-426. By focusing on individual SKUs for subscription products, Dr. Burtis' dataset comprised only 3.7 percent of the revenue for the apps she purported to analyze. 3-SER-426-27.

Compounding these problems, Dr. Burtis did not employ econometric or statistical tests to confirm the validity of her pass-through analysis. 3-SER-422-23. She did not use regressions to control for

variables, she did not test for whether the SKUs she analyzed are representative of others, and she did not use any control group. *Id.* Indeed, Dr. Burtis admitted that her analysis “does not include a study of the economic factors that would explain whether an observed price change was caused by a service fee reduction.” 5-ER-686. Dr. Burtis’ review was confined to a comparison of the price of a single SKU for a product before and after a change in take rate, even if the same product were available at a lower price under a different SKU.

Dr. Burtis’ analysis is also suspect because of the limited data she used. Dr. Burtis’ observations were restricted to narrow time periods. Except for cherry-picked examples, Dr. Burtis analyzed prices only one month and six months before and after the take rate changes, which cannot simulate the long-term effects of lower take rates. 3-SER-418-19. Dr. Burtis then made only simple arithmetic before-and-after calculations, without attempting to control for variables or to test her analysis for economic soundness. 3-SER-422-23.

## **II. PROCEDURAL HISTORY**

The Consumer Class consists of consumers in seventeen states and territories who paid for an app through the Google Play Store or paid for

in-app digital content through Google Play Billing on or after August 16, 2016.<sup>5</sup> 1-ER-29. Plaintiffs moved for class certification in May 2022, and Google simultaneously moved to exclude Dr. Singer's class certification testimony.

On July 19, 2022, following full briefing, the District Court held a concurrent expert proceeding (informally called an "expert hot tub").<sup>6</sup> The District Court questioned both experts, the experts had a chance to explain their analysis and criticize the other's analysis, and each party had an opportunity for cross-examination. 2-ER-40-160. At that proceeding, the District Court scrutinized the experts' testimony "to determine the reliability and confidence of the methods that are going to be used by the economists." 2-ER-45. The experts debated not only Dr. Singer's three models but also Dr. Burtis' analysis. 2-ER-46-143. The District Court subsequently heard argument from counsel. 2-ER-34.

On November 28, 2022, the District Court denied Google's motion to exclude Dr. Singer's testimony and certified the class. 1-ER-3. The

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<sup>5</sup> Plaintiffs initially sought a nationwide class but narrowed the proposed class after attorneys general representing 38 states and the District of Columbia brought *parens patriae* claims. 3-SER-518.

<sup>6</sup> District courts need not hold class certification hearings. See *Bouman v. Block*, 940 F.2d 1211, 1232 (9th Cir. 1991).

District Court first analyzed the admissibility of Dr. Singer's testimony under *Daubert* and found his methodology reliable. 1-ER-10-14. The District Court noted that Google's expert conceded that economists regularly use the Rochet-Tirole and Landes-Posner models. 1-ER-12-13. The District Court also found that Dr. Burtis did not show that the logit model was unreliable as applied to determine the level of pass through to consumers. 1-ER-13-14.

The District Court then turned to Rule 23, finding that plaintiffs had met their burden to show numerosity, typicality, adequacy, and superiority. 1-ER-14, 27-28. The District Court spent the bulk of its rigorous analysis on predominance in tandem with commonality. 1-ER-14-27.

The District Court found that “[c]ommon questions predominate for the antitrust violation element of plaintiffs' claims.” 1-ER-17. The District Court then turned to the antitrust injury element and rejected Google's challenges to Dr. Singer's methods, most of which are repeated to this Court as if a matter of *de novo* review. The District Court also found the “persuasive value” of Google's criticisms of Dr. Singer's reliance on app categories to be “negligible.” 1-ER-21.

The District Court found that the “other idiosyncratic factors” Google raised, including focal point pricing, did not defeat class certification. 1-ER-22 (quotations omitted). The District Court noted that Dr. Singer’s method “can be customized to fit particular situations” and “run at an app-by-app level,” and found that Google’s criticisms did not show that his “analysis falls short on this score.” *Id.* (cleaned up). The District Court also found that Dr. Burtis’ claim of uninjured class members was flawed and of “minimal” persuasive value. 1-ER-23. The District Court concluded that Plaintiffs could prove antitrust impact with common evidence. 1-ER-25.

The District Court did not rely on Dr. Singer’s alternative consumer discount model of injury and damages based on Google’s Play Points program to certify the class. 1-ER-24-25. This model demonstrates class-wide injury through greater discounts that Google would have provided consumers when faced with competition in the but-for world. 5-ER-758-59; 3-SER-497-501. It remains an independent potential basis for class certification.

After analyzing antitrust injury, the District Court turned to damages and concluded that common issues would predominate for the

same reasons that “Plaintiffs have prevailed” on the injury issue, specifically because Plaintiffs have a common method for calculating class-wide damages. 1-ER-25.

## SUMMARY OF THE ARGUMENT

After a rigorous examination of the parties’ respective expert testimony, the District Court found that Plaintiffs can offer admissible, common proof of injury and damages. Given that Plaintiffs’ proof is “capable of resolving a common issue central to the plaintiffs’ claims,” the District Court was well within its discretion to grant class certification. *Olean*, 31 F.4th at 667.

On appeal, Google improperly invites this Court to freshly consider disputed discretionary issues that the District Court appropriately analyzed. Despite passing references to the standards for class certification, Google challenges not so much whether the claims of all class members will turn on common evidence, but instead asks this Court to substitute its judgment for that of the District Court on disputed issues turning on the credibility of the parties’ respective expert witnesses and on the whether particular economic models can prove class-wide impact. Google would have this Court hold that only Dr. Burtis’ analysis could be

found reliable by a jury and disregard the District Court’s findings about the relative credibility of the parties’ experts. This Court should reject Google’s attempt to undermine the role of the District Court and preempt the role of the jury.

*First*, the District Court correctly ruled that the potential for uninjured class members is no bar to class certification. This Court held *en banc* in *Olean* that Rule 23 does not preclude “certification of a class that potentially includes more than a de minimis number of uninjured class members.” *Id.* at 669. In any event, Dr. Singer’s methods demonstrate on a class-wide basis that each class member suffered an injury in the form of higher prices from Google’s sustained, supra-competitive take rate. His methods are well-established, and he applies them reliably to the markets at issue. Despite Google’s suggestion otherwise, Dr. Singer used “real-world data to confirm the accuracy of his predictions.” 1-ER-23. That analysis demonstrates on a class-wide basis that Google’s take rates injured the class members.

Google’s primary contrary evidence was the analysis of its expert, Dr. Burtis. The expert proceeding revealed that Dr. Burtis’ methodology was deeply flawed due to her mistaken focus on SKUs rather than

products. Dr. Burtis missed that for one of the few events studied in her analyses, developers could not “as a practical matter” change their prices for reasons that do not extend to other products. 2-ER-104. She also looked only at narrow time windows, and narrow sets of SKUs that represented tiny slices of developers’ revenue. 2-ER-107-08. More fundamentally, her focus on SKUs made it impossible for her to detect price changes made by changing the SKU under which a product was sold. 2-ER-111-13.

Given these serious flaws, the District Court correctly found that Dr. Burtis’ analysis was “of minimal value,” and that finding was amply supported by the testimony at the concurrent expert proceeding, which the District Court cited in its decision. 1-ER-23. The District Court followed this Court’s precedent in rigorously examining the “dispute between experts,” and concluding that Dr. Singer’s analysis was more credible. *Olean*, 31 F.4th at 676. Google raises no valid basis to upset those findings.

**Second**, the District Court rightly found that Plaintiffs met their burden of proof to demonstrate that common questions would predominate with respect to antitrust injury. The District Court found

that Dr. Singer's testimony was reliable under *Daubert*, that he used well-established economic methods, and that he conducted a rigorous analysis of their fitness to serve as a common model for the class. 1-ER-10-14, 19-25. The District Court also considered and rejected each of Google's various attempts to manufacture individualized issues. Google's arguments to the contrary on appeal rest on a caricatured version of Dr. Singer's analysis and critically ignore the District Court's express findings crediting Dr. Singer's empirical analysis. 1-ER-23.

In one of these arguments, Google contends that Dr. Singer's use of Google's app categories renders his analysis so fundamentally infirm as to be inadmissible under *Daubert*. Google's argument fails because Dr. Singer's use of the categories in his logit model was not an unsupported assumption, but rather was validated by an empirical analysis, which the District Court credited. 1-ER-23; 2-ER-120-21. Moreover, Google's criticisms of its own app categories are based on limited anecdotes, rather than data. In short, the District Court correctly found that Google's attack on Dr. Singer's use of Google's app categories was undeveloped and unconvincing. 1-ER-21.

Google’s focal point pricing arguments likewise fall flat. Dr. Singer considered focal point pricing and determined that it would not hinder pass-through over time in the but-for world. 5-ER-704-07. And even if adjustments for focal point pricing were necessary, as the District Court recognized, Dr. Singer’s “method can be customized to fit particular situations,” including focal point pricing intervals. 1-ER-22; 2-ER-125; 5-ER-705-07. Dr. Singer considered the effect of focal point pricing in his model and accounted for it. That is all that is required for class certification. *See In re Packaged Seafood Prod. Antitrust Litig.*, 332 F.R.D. 308, 343 (S.D. Cal. 2019), *aff’d on reh’g en banc sub nom. Olean*, 31 F.4th 651. Google’s arguments as to whether Dr. Singer or Dr. Burtis better accounted for the issue of focal point pricing are grist for cross-examination, not a basis for exclusion.

**Third**, the District Court correctly found that Dr. Singer’s testimony provided a common method of calculating damages, for the same reasons it correctly resolved the element of antitrust injury. Instead of engaging with that ruling, Google argues that the District Court erred by quoting this Court’s decision in *Leyva* for the proposition that “the presence of individualized damages cannot, by itself, defeat

class certification,” 1-ER-25 (quoting *Leyva*, 716 F.3d at 514). Google’s argument on appeal that this quotation established a new bright-line rule is belied by Google’s reliance on the same case for the same proposition in its district court briefing. 1-ER-25; 3-SER-354 (citing *Leyva* that “individualized damages do not alone defeat class certification”). Neither the District Court’s holding nor its recitation of Ninth Circuit precedent was error.

Given the District Court’s thorough consideration of the evidence, the strength of Plaintiffs’ evidence, the fundamental flaws in Google’s evidence, and the discretionary issues that underlie Google’s appellate arguments, this Court should hold that the District Court did not abuse its discretion in certifying the class.

### **STANDARD OF REVIEW**

This Court reviews “the decision to certify a class and any particular underlying Rule 23 determination involving a discretionary determination for an abuse of discretion.” *Olean*, 31 F.4th at 663 (quotations omitted). This Court reviews “the district court’s determination of underlying legal questions de novo, and its

determination of underlying factual questions for clear error.”<sup>7</sup> *Id.* (cleaned up). The Court will uphold a class certification decision unless the district court “identified or applied the incorrect legal rule or its resolution of the motion resulted from a factual finding that was illogical, implausible, or without support in inferences that may be drawn from the facts in the record.” *Castillo v. Bank of Am., NA*, 980 F.3d 723, 728 (9th Cir. 2020) (cleaned up). In reviewing an order granting class certification, the Court “accord[s] the district court noticeably more deference than when [it] review[s] a denial.” *Jabbari v. Farmer*, 965 F.3d 1001, 1005 (9th Cir. 2020) (quotations omitted); *accord Parsons v. Ryan*, 754 F.3d 657, 673 (9th Cir. 2014).

Despite the deference owed a district court’s class certification decision, Google asserts that this Court reviews *de novo* “whether a statistical model is capable of proving class-wide impact.” Br. 22. That is inaccurate. This Court reviews “the district court’s determination that

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<sup>7</sup> Google cites *Narouz v. Charter Commc’ns, LLC*, 591 F.3d 1261, 1266 (9th Cir. 2010) to note that “traditional deference” to class certification is not warranted when a district court “fails to make sufficient findings.” Br. at 22. In stark contrast to this case, the *Narouz* district court ruled “without providing any findings or providing any analysis of the Rule 23 factors.” 591 F.3d at 1266.

a statistical regression model, along with other expert evidence, is capable of showing class-wide impact, thus satisfying one of the prerequisites of Rule 23 (b)(3) of the Federal Rules of Civil Procedure, for an abuse of discretion.” *Olean*, 31 F.4th at 663. “[A] district court’s class certification decision may be affirmed on any ground supported by the record.” *Castillo*, 980 F.3d at 728.

A district court’s ruling on a motion to exclude expert testimony in connection with a class certification motion is also reviewed for an abuse of discretion. *Grodzitsky v. Am. Honda Motor Co.*, 957 F.3d 979, 984 (9th Cir. 2020).

## ARGUMENT

### I. GOOGLE’S CLAIM OF UNINJURED CLASS MEMBERS IS NOT AN IMPEDIMENT TO CLASS CERTIFICATION

Google’s lead argument on appeal is that the presence of uninjured class members defeats class certification. The Ninth Circuit recently ruled *en banc* that the possible presence of uninjured class members alone does not bar class certification. *Olean*, 31 F.4th at 669 (rejecting “argument that Rule 23 does not permit the certification of a class that potentially includes more than a de minimis number of uninjured class members”). As this Court explained, Rule 23(b)(3) “requires only that the

district court determine after rigorous analysis whether the common question predominates over any individual questions, including individualized questions about injury or entitlement to damages.”<sup>8</sup> *Id.* The District Court fulfilled that obligation by rigorously analyzing both Plaintiffs’ class-wide evidence of injury and Google’s evidence supporting its contention that the class contained uninjured members. 1-ER-23-24. Based on that analysis, the Court rightly determined that individual questions of injury would not predominate.

**A. Plaintiffs Have Offered A Reliable Method To Establish Injury On A Class-Wide Basis**

Plaintiffs’ common proof of class-wide injury is through Dr. Singer’s testimony. As discussed more fully below, the District Court rigorously analyzed Dr. Singer’s economic modeling and found that it could reliably prove on a class-wide basis that each class member was injured. *See infra* Part II. Briefly, Dr. Singer’s analysis demonstrated that developers

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<sup>8</sup> Google cites *Olean* footnote 14 that “a court must consider whether the possible presence of uninjured class members means that the class definition is fatally overbroad.” *Olean*, 31 F.4th at 669 n.14. But Google ignores that “the problem of a potentially over-inclusive class can and often should be solved by refining the class definition rather than by flatly denying class certification on that basis.” *Id.* (quotations omitted). A district court may refine the class definition at any time “before final judgment.” Fed. R. Civ. P. 23(c)(1)(C).

would have charged consumers less if Google’s take rate had been lower. This tracks common sense that costs affect price. 5-ER-748-49. It is also grounded in the analysis of data showing the accuracy of the logit model’s predictions about how an app’s price effects demand for the app.<sup>9</sup> 1-ER-23; 3-SER-492-95; 5-ER-750-53. The District Court correctly found that Dr. Singer’s model shows that Google injured all or nearly all class members. 1-ER-17, 24.

#### **B. The District Court Considered Google’s Evidence Of Uninjured Class Members And Properly Rejected It**

Google maintains that “real-world data” in the form of Dr. Burtis’ analysis of how the prices of SKUs changed after take rate reductions shows that many class members are uninjured. Google suggests that the District Court ignored its evidence and arguments, but that is not true. The District Court rigorously examined the “dispute between the experts,” as required by this Court’s precedents. *Olean*, 31 F.4th at 676. It concluded that Dr. Singer’s analysis was more credible than Dr.

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<sup>9</sup> Google wrongly argues that Dr. Burtis’ analysis was based on “the *only* real-world evidence of developer behavior in the record.” Br. 19. As the District Court explained, “Google’s suggestion that Dr. Singer did not do any empirical analyses is wholly unfounded.” 1-ER-23; *see also infra* Part II.

Burtis', and that Dr. Singer's analysis was reliable enough to support class certification so that the jury could ultimately decide the disputes between the experts.

Ample evidence supports the District Court's findings about the relative probative value of Dr. Singer's and Dr. Burtis' testimony. Google says the Court never identified the "serious questions" about Dr. Burtis' analysis (Br. 19), but the District Court cited twelve pages of transcript from the concurrent expert proceeding in support of its finding that Dr. Burtis' analysis was "of minimal value." 1-ER-23 (citing 2-ER-103-14). The cited pages encompass Dr. Singer's refutation of Dr. Burtis' opinions, which the District Court credited. The problems with Dr. Burtis' work cited by the District Court include:

***First***, Dr. Burtis' analysis of subscription developers was fundamentally flawed. Dr. Burtis claimed that developers did not lower their prices when Google lowered the take rate from 30 to 15 percent fee for users who held a subscription for more than one year. But it was not technically feasible for developers to lower their prices to those subscribers in response to that take rate reduction without also lowering prices for subscribers who were not eligible for the reduced rate. 2-ER-

104; *see also* 3-SER-424-25.

[REDACTED] 3-SER-

309.

**Second,** Dr. Burtis looks at “too narrow of a window.” 2-ER-106-07. Specifically, Dr. Burtis generally looked only at developer prices one to six months after certain limited take rate reductions. 2-ER-107. And in doing so, she ignored that Google systematically eliminated competition and inflated prices for more than a decade, that prices are “sticky,” and that longer time frames are necessary to “model a but-for world in which the take rate was permanently lower from the inception of the Play Store.” *Id.* Dr. Burtis’ analysis of an artificially small window of time seriously undermines the reliability of her conclusion that cost reductions many years ago would not in time lead to price reductions.

**Third,** Dr. Burtis’ narrow focus on prices for individual SKUs developers use to track their sales rather than on prices for products bought by consumers also rendered her analysis unreliable. As Dr. Singer explained at the expert proceeding, Dr. Burtis’ analysis “miss[ed] the forest for the trees.” 2-ER-107-08. For any given consumer, the key question is the product and the price, not which SKU the purchase happened to be sold under. For many apps Dr. Burtis analyzed,

the SKUs she considered represented less than 5 percent of the particular developer's revenue.<sup>10</sup> 2-ER-108 (citing 3-SER-433). Because different SKUs can and are assigned to the same product at different prices, this flaw in Dr. Burtis' analysis renders it unreliable. 1-ER-112-13.

Dr. Burtis' analysis wrongly assumes that developers would implement price changes by discounting the price of a given SKU rather than assigning a different, lower-priced SKU to the product. Indeed, the very example she presented at the expert proceeding, of iHeart Radio, backfired because her analysis missed a price change made through a change in the SKU assigned to the product. 2-ER-111-13. Google now attempts to brush aside Dr. Burtis' hand-picked example as but one example, but the District Court correctly noted that the problem "is endemic to her analysis." 2-ER-113.

Google calls it "remarkable" that Dr. Burtis found that 93 percent of the SKUs never changed price. Br. 29. But the obvious alternative

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<sup>10</sup> Google appears to misunderstand Dr. Singer's testimony that the SKUs Dr. Burtis analyzed "touched such a small percentage of the app developer's revenues at issue." Br. 37 (quoting 2-ER-108). In the but-for world, a service fee reduction would touch all of a developer's revenue from the start, rather than just the small slices Dr. Burtis analyzed. 2-ER-107-08; 3-SER-433.

explanation for that finding is that developers often change prices for a product by changing the SKU. Dr. Burtis did not even consider that obvious possibility or deliberately chose to ignore it.

Given these profound flaws in Dr. Burtis' analysis, the District Court acted well within its discretion in discounting her opinions. *See Olean*, 31 F.4th at 680-81. Google asks this Court to credit its expert's methodology instead of Dr. Singer's and to remove the question of an expert's persuasiveness from the jury. But the District Court's findings were not "illogical, implausible, or without support in inferences that may be drawn from the facts in the record." *Castillo*, 980 F.3d at 728 (quotations omitted). There is no basis for this Court to substitute its judgment for that of the District Court on these fact-intensive issues.

Even if Dr. Burtis' analysis were not fundamentally flawed (and it is), it does not demonstrate that any class member was uninjured. A class member is uninjured only if that consumer made no purchases of any app or in-app content at inflated prices. Dr. Burtis looked solely at certain limited purchases of particular apps with particular SKUs. The class is made up of individual purchasers, not individual SKUs. Dr. Burtis did not even take the necessary step of determining that all

purchases made by any particular individuals only contained SKUs for which she found no pass-through.<sup>11</sup> She did not identify even a single class member who was uninjured. Regardless, the entirety of Dr. Burtis' analysis was flawed and does not show what would happen to prices in the but-for world with competition and lower take rates.

Apart from Dr. Burtis' analysis, Google points only to anecdotal evidence from three developer plaintiffs—whose own damages depended on showing a lack of pass-through—who unsurprisingly said they did not lower their prices. Br. 30-31. But such testimony does not introduce significant individualized issues. As Dr. Singer noted, there are significant economic reasons to think that developers would react

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<sup>11</sup> Google overstates Dr. Burtis' conclusion that “at least 93% of transactions involved potentially uninjured plaintiffs.” Br. 31. Even assuming that Dr. Burtis analyzed data that could provide insight into competitive conditions in the but-for world, 47 percent of consumers purchased *none* of the SKUs Dr. Burtis analyzed. 5-ER-684. Because she did not determine whether her sample is representative, 3-SER-422-23, her analysis tells us nothing about the majority of class members who were not included in the limited dataset used in her analysis. While Google cites Dr. Burtis' finding that 41 percent of consumers purchased from only one app, 2-ER-260, she does not say whether *any* of the SKUs she analyzed were the sole purchase of *any* consumer, *id.*

differently in the but-for world with long-term lower take rates than to Google's limited take rate reductions in the real world. 3-SER-421.

Google relies heavily on *Van v. LLR, Inc.*, 61 F.4th 1053 (9th Cir. 2023), but *Van* is off point. In *Van*, the defendants introduced conclusive evidence that 18 class members had not been injured in the form of purchase records showing that they received a discount "for the purpose of offsetting the improperly assessed sales tax." *Id.* at 1068. Determining whether other class members were similarly uninjured would have required the individual analysis of 13,680 class members' purchase records to determine the purpose of discounts they received. *Id.* at 1068-69. Here, by contrast, the question of pass-through can be resolved using common evidence.<sup>12</sup>

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<sup>12</sup> Google criticizes the District Court's analogy to price fixing cases (Br. 34-35), but the analogy is sound. Google argued in the District Court that individualized questions concerning Google's negotiations with developers over its take rate would predominate. 3-SER-349-51. The District Court correctly rejected that argument because Google's conduct inflated the "headline rate," "creating an inference of class-wide impact even when prices are individually negotiated," just as in price-fixing cases. 1-ER-23-24 (quoting *Olean*, 31 F.4th at 671). In any event, the District Court was clear that it was "not deciding the question of certification here on the basis of price fixing cases." 1-ER-24.

Dr. Singer has provided economic evidence that all class members were injured. Google's contrary evidence of non-injury is almost identical to that of defendants in *Olean*. There, the defense expert "did not make a factual finding that 28 percent of the DPP class or 169 class members were uninjured." *Olean*, 31 F.4th at 680. So too here—Dr. Burtis' analysis seeks to demonstrate that pass-through was rare to "undermin[e] confidence in" Dr. Singer's model. *Id.*; 5-ER-689 & n.344. Even had the District Court credited Dr. Burtis' SKU-based methods, it is a common method that can be applied mechanically to demonstrate non-injury across the class. See *Olean*, 31 F.4th at 681 ("[I]f the jury were persuaded by [defense expert's] critique, the jury could conclude that [plaintiffs] had failed to prove antitrust impact on a class-wide basis."). Thus, Google's illusory evidence of the non-existence of pass-through does not "invoke[] an individualized issue." *Van*, 61 F.4th at 1069. Faced with this form of expert dispute, the District Court rightly "resolved th[e] methodological dispute between the experts," and concluded that the question of class-wide injury is a merits issue.<sup>13</sup> *Olean*, 31 F.4th at 680.

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<sup>13</sup> Google's out-of-circuit precedent features individualized questions that are not present here or in *Olean*. Because of these factual distinctions,

### C. Article III Standing Exists For Class Certification

In *Olean*, this Court rejected the proposition that “no class may be certified that contains members lacking Article III standing.” 31 F.4th at 682 n.32 (quotations omitted). It held instead that the plaintiffs had shown that “all class members have standing” by coming forward with a reliable method of establishing class-wide injury. *Id.* at 682. In much the same way, Plaintiffs have shown that all class members have standing. Dr. Singer’s model reliably shows that Google caused injury to the entire class through its unlawful monopolistic behavior. Because Plaintiffs’ “evidence was capable of establishing antitrust impact on a class-wide basis,” Plaintiffs have shown “Article III standing at the class certification stage for all class members, whether or not that was required.” *Id.* (citing *Transunion v. Ramirez*, 141 S. Ct. 2190, 2208 n.4 (2021)); *see* 1-ER-23.

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*Olean* did not create a circuit split. 31 F.4th at 669 n.13; *In re Asacol Antitrust Litig.*, 907 F.3d 42, 51 (1st Cir. 2018) (individualized inquiries of whether class members would choose to purchase brand drug over generic); *In re Rail Freight*, 934 F.3d 619 (D.C. Cir. 2019) (plaintiffs “proposed no further way—short of full-blown, individual trials” to prove injury).

## II. THE DISTRICT COURT CORRECTLY DETERMINED THAT COMMON QUESTIONS OF ANTITRUST IMPACT PREDOMINATE

Rule 23 (b)(3) requires that common questions “predominate over any questions affecting only individual class members.” *Amgen*, 568 U.S. at 469 (cleaned up). For Plaintiffs to establish that common questions predominate, they must show “that essential elements of the cause of action . . . are capable of being established through a common body of evidence, applicable to the whole class.”<sup>14</sup> *Olean*, 31 F.4th at 666 (quotations omitted).

The District Court correctly resolved predominance in Plaintiffs’ favor: “In the end, the record establishes that plaintiffs satisfied their burden of proof.” 1-ER-16. The core of that finding was the District Court’s rigorous analysis of Plaintiffs’ common evidence of antitrust injury. *First*, the District Court correctly concluded that Dr. Singer’s

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<sup>14</sup> Antitrust plaintiffs must show “(i) the existence of an antitrust violation; (ii) antitrust injury or impact flowing from that violation (i.e., the conspiracy); and (iii) measurable damages.” *Olean*, 31 F.4th at 666 (quotations omitted). On appeal, Google challenges the District Court’s findings only with respect to antitrust injury and damages. “Google did not separately challenge plaintiffs’ Rule 23 showing for the Cartwright Act and UCL claims brought under California law,” but the District Court “independently examined the state law claims” and determined class certification was appropriate. 1-ER-25-27.

models were both admissible under *Daubert* and “suitable as an element of classwide proof of antitrust impact and injury.” 1-ER-10-14, 19-20. *Second*, as part of its rigorous analysis, the District Court considered and rejected the “blunderbuss of objections” to Dr. Singer’s methods which Google said would introduce significant individualized issues, including focal point pricing and Dr. Singer’s use of Google’s app categories. 1-ER-20-25. The District Court concluded that “[a]s is the case for all of Google’s attacks on Dr. Singer, it may argue the point at trial, . . . but it does not erode plaintiffs’ showing of common evidence to prove antitrust impact.” 1-ER-25.

#### **A. Dr. Singer’s Models Are Reliable Common Proof Of Antitrust Impact**

The District Court properly recognized that “Plaintiffs rely on Dr. Singer’s analysis as their common method of proving antitrust impact.” 1-ER-17. Accordingly, the District Court noted its role of determining “if the expert’s methodology ‘is capable of showing class-wide antitrust impact’ in light of ‘factors that may undercut the model’s reliability . . . and resolve[d] disputes raised by the parties.’” 1-ER-9 (quoting *Olean*, 31 F.4th at 683). Class certification does not require that plaintiffs establish they will prevail at trial, only that the case to be

presented will be fundamentally the same for all class members. If the proof, including expert testimony, to be presented is the same as would be presented in an individual trial, the requirements of Rule 23 are met. *Tyson Foods, Inc. v. Bouaphakeo*, 577 U.S. 442, 455 (2016).

The District Court properly found both that Dr. Singer's testimony is admissible under *Daubert*, and that it satisfies Rule 23's requirements.

*First*, the District Court properly assessed the admissibility of Dr. Singer's testimony under the appropriate *Daubert* standard. An expert's opinion rests on a proper foundation when “the knowledge underlying it has a reliable basis in the knowledge and experience of the relevant discipline.” *Elosu v. Middlefork Ranch Inc.*, 26 F.4th 1017, 1024 (9th Cir. 2022) (quotations omitted).<sup>15</sup> “The test under *Daubert* is not the correctness of the expert's conclusions but the soundness of his methodology.” *Primiano v. Cook*, 598 F.3d 558, 564 (9th Cir. 2010)

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<sup>15</sup> Amicus Atlantic Legal Foundation argues that the District Court should have departed from Ninth Circuit precedent given forthcoming amendments to the Federal Rules. ECF 25. That argument lacks merit, but in any event Dr. Singer's analysis satisfies *Daubert* under either standard.

(cleaned up).<sup>16</sup> Applying these standards, the District Court properly found Dr. Singer's testimony admissible. 1-ER-10-14.

*Second*, the District Court found that Dr. Singer's model could serve as common proof of antitrust injury. "The determination whether expert evidence is capable of resolving a class-wide question in one stroke may include weighing conflicting expert testimony and resolving expert disputes where necessary to ensure that Rule 23(b)(3)'s requirements are met." *Olean*, 31 F.4th at 666 (cleaned up). In making that determination, "a district court is limited to resolving whether the evidence establishes that a common question is *capable* of class-wide resolution, not whether the evidence in fact establishes that plaintiffs would win at trial." *Id.* at 666-67. Based on the admitted expert testimony, the District Court correctly found that the question of injury "is *capable* of class-wide resolution." *Id.* at 667. Google offers no persuasive proof to the contrary.

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<sup>16</sup> At the class certification stage, even a contrary finding on *Daubert* would not be dispositive, as "an inquiry into the evidence's ultimate admissibility should go to the weight that evidence is given at the class certification stage." *Sali v. Corona Reg'l Med. Ctr.*, 909 F.3d 996, 1006 (9th Cir. 2018).

## **1. Dr. Singer’s Model Employs Widely Accepted Economic Methods**

Dr. Singer applies reliable and well-established economic techniques in his modeling of antitrust injury. As the District Court found, economists regularly use each of the models Dr. Singer employs. Dr. Singer uses two models, the Rochet-Tirole and Landes-Posner models, to calculate how Google’s take rate would decline in the but-for world. 1-ER-19-20 (citing 5-ER-729-30, 743-46). Dr. Burtis conceded that both models are used in the literature. 1-ER-12-13; 2-ER-55, 2-ER-83. Dr. Singer then uses the logit model to calculate how the take rate reduction would affect consumer prices. 1-ER-20 (citing 5-ER-754). Putting the output of those models together, Dr. Singer calculates consumer damages. 1-ER-20 (citing 5-ER-744). As the District Court recognized, “Google has not suggested that this overall approach is ‘junk science’ destined for the scrap heap under *Daubert*.” 1-ER-12.

Logit is a well-accepted model employed in analogous situations. Economists and courts use logit in the merger context to determine, for instance, whether combining firms will lead to lower consumer prices, and if so, by how much. As Dr. Singer put it, “the logit model is commonly used to map a change in the merging parties’ costs that come about from

merger synergies into a change in price.” 2-ER-100. In support, he pointed to peer-reviewed literature confirming logit’s use by the Department of Justice in merger analysis. 1-SER-26. Other peer-reviewed literature confirms that logit is “commonly employed in antitrust analysis of mergers involving differentiated products.” 1-SER-47.

Dr. Singer’s use of logit is closely analogous to merger applications. In merger analysis, logit is used to examine whether and how “the cost advantages of large firms can be extended through merger,” that is, how lower marginal costs from merger synergies affect consumer prices. 1-SER-37. In that context, logit predicts the effect that hypothetical cost reductions from merger synergies will have on the prices consumers pay. 1-SER-38. Dr. Singer explained at the evidentiary hearing how his use of the logit model in this case likewise considers a hypothetical cost reduction’s impact on consumer prices. 2-ER-100 (“If you think about it, it’s precisely what I’m trying to do here. I need a model that would allow me to map a change in cost that come[s] about from a lower take rate into a change in the app developer’s pricing.”).

Dr. Singer also explained how economists have used logit to calculate pass-through in other related contexts. 2-ER-99-101. For example, economists have used logit to calculate pass-through effects from cartels. Frank Verboven & Theon Van Dijk, *Cartel Damages Claims and the Passing-On Defense*, 57 J. Indus. Econ. 457, 473-75 (2009). Economists have also used it to examine the extent to which reductions in wholesale prices are passed on to consumers, *see* K. Sudhir, *Structural Analysis of Manufacturer Pricing in the Presence of a Strategic Retailer*, 20(3) Marketing Sci. 244-64 (2001), and the economic effects of price discrimination, *see* Simon Cowan, *Third-Degree Price Discrimination and Consumer Surplus*, 60(2) J. Indus. Econ. 333-45 (2012). As Dr. Burtis conceded, the “logit demand model is used frequently in the literature” for many applications.<sup>17</sup> 2-ER-97.

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<sup>17</sup> Given logit models’ widespread use in economics, courts have accepted damages models which calculate consumer price impacts using logit. *See, e.g., Allegro v. Luxottica Retail N. Am.*, 341 F.R.D. 373, 450-55 (E.D.N.Y. 2022) (denying motion to exclude analysis of deceptive trade practice on consumer prices based on logit model); *In re Gen. Motors Corp. Air Conditioning Mktg. & Sales Pracs. Litig.*, No. 18-MD-02818, 2023 WL 2215953, at \*10-\*12 (E.D. Mich. Feb. 24, 2023) (denying motion to exclude mixed logit model used to calculate class-wide damages).

Despite logit's widespread use in economics both to calculate pass-through and for other purposes, Google attacks Dr. Singer's analysis by arguing that “[n]o one has ever used a logit model to calculate pass-through and show individual injury before.” Br. 11. That argument is disingenuous. As discussed above, logit models are regularly used to calculate pass-through, 1-SER-26; 1-SER-47, and to calculate consumer injury from price effects. Br. 40; 2-ER-100; 1-SER-26; *Allegra*, 341 F.R.D. at 450-55. If anything, that experts rely on a methodology outside the litigation context strengthens its admissibility, as it suggests that the method has a “reliable basis in the knowledge and experience of the relevant discipline.” *Elosu*, 26 F.4th at 1024 (quotations omitted).

Google argues that peer-reviewed publications do not exist supporting the use of logit under the precise circumstances presented here. Br. 16. Even setting aside Dr. Burtis' concession that the logit formula Dr. Singer employed came from a peer-reviewed publication, 2-ER-96, *Daubert* does not require that. As the District Court explained by quoting the Supreme Court's decision in *Kumho Tire*: “The ‘gatekeeping inquiry must be tied to the facts of a particular case,’ and so it is not necessarily ‘surprising’ for expert opinions to be based on methods that

are new and not been the subject of peer review.” 1-ER-13 (quoting *Kumho Tire Co. v. Carmichael*, 526 U.S. 137, 150-51 (1999)). The District Court credited Dr. Singer’s testimony that the logit model “has been used in the merger context” and that he ran “tests to confirm that the model fit the data here.” 1-ER-13. Nothing more is required. *See Olean*, 31 F.4th at 665 (“In carrying the burden of proving facts necessary for certifying a class under Rule 23(b)(3), plaintiffs may use any admissible evidence.”)

## **2. Dr. Singer Reliably Applied Economic Methods On A Class-Wide Basis**

The District Court correctly determined that Dr. Singer reliably applied his methods to the facts of the case, *see Fed. R. Evid. 702(d)*, and that those methods could prove injury for the full class, *Olean*, 31 F.4th at 666-67. The question is not whether Dr. Singer’s analysis is perfect. As this Court has explained: “Imperfect application of methodology may not render expert testimony unreliable because a minor flaw in an expert’s reasoning or a slight modification of an otherwise reliable method does not render expert testimony inadmissible.” *Hardeman v. Monsanto Co.*, 997 F.3d 941, 962 (9th Cir. 2021) (cleaned up). Even “deference to experts with borderline opinions” is proper under *Daubert*,

as “the interests of justice favor leaving difficult issues in the hands of the jury and relying on the safeguards of the adversary system to attack shaky but admissible evidence.” *Id.* at 962 (cleaned up).

The District Court discussed Dr. Singer’s analysis set forth in his report and at the expert proceeding, finding that “Dr. Singer tested the fit between the logit demand model and the transactional data available to him, and he ‘found a very tight fit’ for every category.” 1-ER-12 (quoting 2-ER-121). As Dr. Singer explained in testimony cited by the District Court, his regression analysis confirmed that logit’s predictions were accurate and gave him confidence that “the logit model is reliable to make predictions in the but-for world.” 2-ER-120-21.

Ignoring that Dr. Singer used accepted economic methods to confirm the application of his models, Google resorts to superficial arguments.<sup>18</sup> While it raised many such scattershot arguments in the District Court, here it focuses on two of them. *See* 03-SER-345-48; 03-SER-333-40. First, Google contends that Dr. Singer’s methodology is

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<sup>18</sup> Instead of directly asserting that the District Court abused its discretion in finding Dr. Singer reliable, Google wrongly couches its arguments in terms of *de novo* review, even though these are issues within a district court’s discretion.

unreliable because he used Google's own app categories to determine when apps compete against one another. Second, Google argues that Dr. Singer's methodology is unreliable by contending that he did not properly account for focal point pricing.

**A. Dr. Singer's Analysis Reliably Used Google's App Categories**

The District Court found that "Dr. Singer's use of the Google Play Store categories is reasonable in light of the evidence," and that "his approach to those categories does not make his analyses incapable of showing classwide impact." 1-ER-22. Google asks this Court to reject that finding, on the ground that apps in each category are not good substitutes for each other. The District Court found that "Google made the point mainly as an observation, rather than a well-formulated analysis, and its persuasive value is negligible." 1-ER-21. Whether analyzed as a *Daubert* issue or class certification issue, the District Court's finding is amply supported by the evidence.

As the District Court found, considerable record evidence undermines Google's claim that the app categories "are not based on any

economic analysis or reasoning.” Br. 6.<sup>19</sup> Google uses the app categories for its own internal consumer surveys and analyses of consumer spending patterns, suggesting that Google finds them to be reliable enough to inform its decision-making. 3-SER-315-323; 5-ER-711. Third-party industry analysts and developers rely on the categories too. 5-ER-711-12.

Google also ignores the only empirical record evidence about substitution within Google’s app categories. The District Court found that Dr. Singer “ran multiple tests using that real-world data to confirm the accuracy of his predictions about such things as ‘the relationship between an app’s share within its category and its price.’” 1-ER-23 (quoting 2-ER-120). As Dr. Singer explained in testimony the District Court quoted, “the data obeyed the prediction of the logit model.” 2-ER-121. Put differently, Dr. Singer’s regressions show that when prices rose for an app within a category, consumer demand shifted to other apps in

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<sup>19</sup> As the District Court noted, Dr. Daniel McFadden used Apple’s app categories to model demand in the *Apple* litigation. 1-ER-21. Google takes issue with this because the expert in *Apple* did not use logit and because a class has not yet been certified in that case. Br. 51. But the fact remains that another leading economist concluded that it was appropriate to use similar evidence in analogous circumstances.

that category, following the pattern the logit model predicted. 3-SER-493-95. Dr. Singer's use of the categories was not an "unsupported assumption" as Google suggests (Br. 44); Dr. Singer's empirical work validated it.<sup>20</sup> Together, the weight of the evidence strongly supports Dr. Singer's use of Google's app categories.

Even if Google were correct that all apps within a category are not perfect substitutes, it would not undermine the reliability of Dr. Singer's logit model. It is unnecessary to determine which apps in each category are perfect substitutes "to get the implied pass-through rate." 2-ER-183-84. Logit does not require perfect substitutability. Indeed, logit is often applied in markets with unique products (or, in economic jargon, product differentiation) where each product will not be a perfect substitute for every other product. 1-SER-26.

The District Court was right to conclude that Google had not developed its argument as to why using the Google app categories in Dr. Singer's logit model precludes class certification. Google's *Daubert* brief in the District Court devoted one paragraph to it. *See* 3-SER-339. When

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<sup>20</sup> Google has no empirical evidence that substitution does not occur between apps in a category. Both at the district court and on appeal, Google relies on analogies and anecdotes.

pressed by the District Court as to how the category issue would “affect the output for [the logit] equation,” Dr. Burtis had no responsive answer. 2-ER-130-31.

Dr. Singer’s regression analysis confirmed that the logit model reliably models demand within Google’s app categories even if not all apps in each category are perfect substitutes. 1-ER-23; 2-ER-120; 5-ER-750-53. Google was unable to make any showing in the District Court that the lack of complete substitutability materially impacted the results of Dr. Singer’s logit model, and the District Court therefore correctly rejected Google’s “undeveloped” arguments.

**B. The District Court Appropriately Addressed Google’s Faulty Focal Point Pricing Argument**

Google argues that developers’ prices are unaffected by their costs because of focal point pricing, which it defines as “the practice of setting prices that end in 99-cent increments.” Br. 44. Google contends that focal point pricing would result in a significant number of uninjured class members, thereby raising individualized questions. Br. 20-21.

The District Court correctly considered and rejected this challenge, to which Google devoted only a page in its briefing below. *See* 3-SER-

346-47; 3-SER-338-39. The District Court reasoned that the issue of focal point pricing was not significant enough to “demonstrate[] that Dr. Singer’s analysis falls short.” 1-ER-22. The District Court further found that Dr. Singer’s “method can be customized to fit particular situations” to account for the individualized factors Google identified such as focal point pricing. 1-ER-22. Because Dr. Singer’s models can be run on an app-by-app basis, it is possible to test Google’s focal point pricing critique, and to make adjustments for it if necessary, without resorting to any individualized analysis. *Id.*; 5-ER-705-07.

As the District Court recognized, Dr. Singer could calculate damages “on an app-by-app level” as a “mechanical” matter to account for focal point pricing. 2-ER-125; *see also* 5-ER-705-07; 5-ER-763 n.592 (“Class member-specific damages would then be calculated based on a Class member’s expenditures at different developers.”). Dr. Singer’s methodology can account for developers who have received special take-rate deals with proportional adjustments to but-for take rates. 5-ER-763-64. He would then apply their pass-through rates from logit to determine the change in price, and accordingly damages, in the but-for world. 5-ER-763.

As Dr. Singer illustrated in his reply report, his damages model can also accommodate focal point intervals by adjusting logit's new predicted profit-maximizing price. 5-ER-705. For instance, if logit predicts a price reduction to a list price of \$2.03 would be profit-maximizing, Dr. Singer's model could accommodate adjusting the reduction to the nearest focal point interval (meaning a reduction to \$1.99). 5-ER-705-07. To the extent that those adjustments result in small numbers of uninjured class members, the class definition can be adjusted at that time. *See Olean*, 31 F.4th at 669 n.14.

Google's reliance on focal point pricing should also be rejected because there is substantial record evidence that developers are willing to depart from focal point pricing and did not do so largely because of Google's conduct. Google imposed a 99-cent price floor until early 2022, after the end of the transaction data available at class certification. 5-ER-705-06. Google eventually lowered the 99-cent minimum price to 5 cents at the request of developers, who had "tested sub dollar pricing and [found] this strategy effective." 5-ER-705-06 & n.58.

Likewise, Google's prohibition on steering removes incentives for developers to depart from focal point intervals. In a but-for world where

developers could redirect consumers to alternative platforms to complete in-app transactions, they would be incentivized to use discounts to direct consumers to lower-priced platforms. 5-ER-706-07. Google's contractual anti-steering provisions (a centerpiece of the litigation) improperly removed these incentives, to the harm of consumers. Google's quotation of Dr. Singer's testimony that focal point pricing is an "important consideration" in the actual world, ignores this substantial evidence showing that focal point pricing would not affect the but-for world once Google's anticompetitive conduct is remedied. 1-SER-15-22. It would be improper to allow Google's anticompetitive conduct to be considered an acceptable part of the but-for world. *Cf. Apple*, 139 S. Ct. at 1523 (rejecting theory that "would provide a roadmap for monopolistic retailers to structure transactions with manufacturers or suppliers so as to evade antitrust claims by consumers.")

Nor is there any valid support for Google's argument that in a competitive world focal point pricing inevitably leads developers to price in 99-cent increments, rather than prices that end in 9 or 5 or other numbers. Dr. Singer cited real-world evidence and literature indicating that focal point pricing for lower-priced items is often characterized by

intervals of 10 cents rather than \$1. 5-ER-706-07 & nn.60-62. The Play Store data bears this out, as pricing data shows “prices at regular, ten-cent intervals.” *Id.* More than 20 percent of the top paid apps have prices that do not end in “99,” and over 130 million transactions were completed at prices that do not end in “99,” even while Google’s 99-cent price floor was in effect. 5-ER-704, 706-07.

This case is unlike the ones cited by Google, where record evidence overwhelmingly showed that focal point pricing would preclude price changes in the but-for world. There is no *per se* rule that focal point pricing precludes reliable findings of class-wide injury and damages. *See In re Packaged Seafood*, 332 F.R.D. at 343 (“The Court is not persuaded” by defendants’ argument that an expert “ignored loss-leader and focal point pricing” because the expert “in fact discusses both in his report.”), *aff’d on reh’g en banc sub nom. Olean*, 31 F.4th 651. In the cases Google cites, experts failed to account for overwhelming record evidence. *In re Apple iPhone Antitrust Litig.*, No. 11-cv-6714, 2022 WL 1284104, at \*8 (N.D. Cal. Mar. 29, 2022) (expert should have considered focal point pricing where record included “overwhelming evidence” of focal point pricing in but-for world, including expert’s own admission); *In*

*re Lithium Ion Batteries Antitrust Litig.*, No. 13-MD-2420, 2018 WL 1156797, at \*4 (N.D. Cal. Mar. 5, 2018) (theory of pass-through based on lower quality to compensate for battery costs in laptops was unsupported by record); *In re Optical Disk Drive Antitrust Litig.*, 303 F.R.D. 311, 324-25 (N.D. Cal. 2014) (pass-through of cost that is “relatively small portion of the cost” of products priced at \$100 increments defeated class certification).

The same cannot be said here given Dr. Singer’s examination of focal point pricing and why it would not affect his opinions. The District Court reasonably found that Google’s arguments were points for cross-examination at trial, not for exclusion or denial of class certification. “[A] district court cannot decline certification merely because it considers plaintiffs’ evidence relating to the common question to be unpersuasive and unlikely to succeed in carrying the plaintiffs’ burden of proof on that issue.” *Olean*, 31 F.4th at 667.

### **C. The District Court Appropriately Rejected Google’s Other Claimed Individualized Questions**

In the District Court, Google raised a host of other purported “idiosyncratic factors” that it claims Dr. Singer did not take into account.

1-ER-20-22; 3-SER-345-54. The District Court rigorously analyzed and rejected these arguments, including that Dr. Singer allegedly failed to properly consider developers' marginal costs, and for the most part Google does not take issue with its findings. 1-ER-20-25. But Google's brief is laced with a smattering of these renewed criticisms. Google argues in passing that Dr. Singer "does not account for the competitive conditions of each individual app, which naturally affect how developers set prices." Br. 41. Elsewhere, Google argues that "the court deemed it irrelevant for Rule 23 purposes that Dr. Singer's model did not attempt to control for these independent variables." Br. 49. And Google also faults the District Court for supposedly acknowledging that the case presents "individualized questions on impact and damages," but failing to "identify what those questions were." Br. 17 (quoting 1-ER-28). Google's arguments on this score consistently ignore the rigorous empirical analysis Dr. Singer conducted, and the District Court's findings crediting his analysis.

Dr. Singer's regression analysis controlled "for App-specific characteristics" and confirmed the validity of his logit model. 3-SER-

492.<sup>21</sup> The District Court found that “[t]he record, namely his report and hot tub testimony, amply establish that his opinions were solidly grounded in the transactional data and other evidence in the case.” 1-ER-23. The District Court also rejected “Google’s suggestion that Dr. Singer did not do any empirical analyses” as “wholly unfounded.” *Id.* Finally, the District Court found it significant that Dr. Singer’s models “can be used to drill down further and make calculations at an app-by-app level.” 1-ER-25. In short, the District Court properly found that Dr. Singer’s logit model adequately accounted for, and explained, the relevant competitive conditions through rigorous empirical work.

In sum, the District Court considered each of the purported individualized issues Google relies on in this appeal and correctly found that none is a bar to class certification. This is precisely the sort of “rigorous assessment of the available evidence and . . . methods” that

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<sup>21</sup> Google argues elsewhere that Dr. Singer fails to control for variables that could affect prices, and cites cases that denied certification on those grounds. Br. 39 & n.5. These arguments again ignore Dr. Singer’s regression analysis, which employed fixed effects to control for other factors and concluded his logit model accurately describes demand for apps. 5-ER-750-53.

Ninth Circuit precedent requires. *Olean*, 31 F.4th at 666 (quotations omitted).

**B. The District Court Did Not Flip The Burden Of Proof Or Ignore Individualized Issues**

Google at various points argues that the District Court “misallocate[ed] the burden of proof at class certification.” Br. 35, 55. This mischaracterizes the District Court’s decision. The District Court was clear on who bore the burden: “In the end, the record establishes that plaintiffs satisfied their burden of proof on these elements.” 1-ER-16. The District Court’s rejection of Google’s arguments followed pages of analysis of Dr. Singer’s testimony, finding that his methods were reliable. 1-ER-14, 1-ER-10-13. A District Court does not flip the burden of proof by “observing that the party’s rebuttal evidence is unconvincing,” especially after detailing why the evidence from the party with the burden of proof is persuasive. *Robinson v. Ardoin*, 37 F.4th 208, 227 (5th Cir. 2022); *see also Helper v. West*, 174 F.3d 1332, 1336 (Fed. Cir. 1999) (“For a court to note the weaknesses in one party’s arguments does not mean that it is treating that party as bearing the burden of proof.”); *Olean*, 31 F.4th at 681 (“The district court’s conclusion that the [defendants] could present [their expert’s] critique at trial did not

improperly shift the burden of determining whether the Rule 23(b)(3) prerequisites were met to the jury.”). That is how district courts appropriately consider arguments.

### **III. THE DISTRICT COURT CORRECTLY DETERMINED THAT INDIVIDUALIZED DAMAGES ISSUES WOULD NOT PREDOMINATE**

Google asks this Court to vacate the District Court’s class certification decision on the feigned ground that it failed to analyze whether individual damage issues would predominate. This argument lacks merit.

Rule 23(b)(3)’s predominance requirement takes “into account questions of damages.” *Just Film, Inc. v. Buono*, 847 F.3d 1108, 1120 (9th Cir. 2017). Plaintiffs must show “that their damages stemmed from the defendant’s actions that created the legal liability.” *Id.* (quotations omitted). Damages stem from a defendant’s action when “the whole class suffered damages traceable to the same injurious course of conduct underlying the plaintiffs’ legal theory.” *Id.* To meet this traceability requirement, plaintiffs must show “a class wide method for damages calculations.” *Lambert ex rel. Situated v. Nutraceutical Corp.*, 870 F.3d 1170, 1182 (9th Cir. 2017).

The District Court correctly found that Dr. Singer's model provided a "common methodology" to show both injury and damages. 1-ER-25. Plaintiffs' damages model is highly administrable. As in *Olean*, Dr. Singer's model can calculate each class member's damages using Google's sales records and "a straightforward process of applying the class-wide" service fee with each app's pass-through rate. *Olean*, 31 F.4th at 682 n.31; 5-ER-763-66.

Because Dr. Singer uses the same common method for class-wide injury and damages, *see* 5-ER-763-66; 1-ER-22, 25, the District Court correctly rejected the argument that Plaintiffs had not shown a common method for showing class-wide damages:

Google says that plaintiffs lack a common method of calculating class-wide damages "for the same reasons they lack common proof of impact." Dkt. No. 273 at 21-22. *Plaintiffs have prevailed on that issue, and Google's damages attacks are overruled on the same grounds.*

1-ER-25 (emphasis added). There is no error in applying its considered ruling on antitrust impact to damages. *See In re Packaged Seafood Prod. Antitrust Litig.*, 332 F.R.D. at 328 (applying ruling from antitrust impact to damages because "Defendants raise[d] no arguments not already

raised with regard to the reliability of [the expert's] model"), *aff'd on reh'g en banc sub nom. Olean*, 31 F.4th 651.

The District Court then added that individualized damages calculations could not defeat certification because Dr. Singer's common methodology could calculate each class member's damages:

The Court adds that it is well-established circuit law that "damage calculations alone cannot defeat certification," *Yokoyama v. Midland Nat'l Life Ins. Co.*, 594 F.3d 1087, 1094 (9th Cir. 2010), and "the presence of individualized damages cannot, by itself, defeat class certification under Rule 23(b)(3)." *Leyva*, 716 F.3d at 514. Dr. Singer has stated how his common methodology can be used to drill down further and make calculations at an app-by-app level.

1-ER-25. In other words, the District Court—as in *Olean*—found that Dr. Singer's "proposal for calculating damages is a straightforward process." 31 F.4th at 682 n.31. That is all the law requires.

Google resists this conclusion by claiming that it was "legal error" for the District Court to quote this Court's decision in *Leyva*, 716 F.3d at 514, that "individualized damages questions 'cannot, by itself, defeat class certification.'" Br. 55-56 (quoting 1-ER-25). Google interprets that quote as an improper "bright-line rule that individualized damages calculations can never defeat class certification." Br. 57. But the District Court did not rely on any sort of bright-line rule. As discussed above, it

recognized that Dr. Singer had a methodology to prove injury and damages on a class-wide basis using common proof. *See 1-ER-25.*

Plus, the District Court properly quoted *Leyva*. Google itself cited *Leyva* to the District Court for the proposition that “individualized damages do not alone defeat certification.” 3-SER-354. And the post-*Yokoyama* and *Leyva* cases that Google now cites use language like that the District Court quoted. *See Bowerman v. Field Asset Servs. Inc.*, 60 F.4th 459, 469 (9th Cir. 2023) (“[A]s we have emphasized, ‘the presence of individualized damages cannot, by itself, defeat class certification.’” (quoting *Leyva*, 716 F.3d at 514)); *Olean*, 31 F.4th at 668-69 (“[A] district court is not precluded from certifying a class even if plaintiffs may have to prove individualized damages at trial.”); *Lambert*, 870 F.3d at 1182 (“[U]ncertain damages calculations alone cannot defeat class certification.”), *rev’d and remanded*, 139 S. Ct. 710 (2019); *Doyle v. Chrysler Grp., LLC*, 663 F. App’x 576, 579 (9th Cir. 2016) (“[O]ur court has emphasized that the need for individualized findings as to the amount of damages does not defeat class certification.” (quotations omitted)). These cases are not outliers. Dozens of this Court’s decisions

have used similar language as that quoted from *Yokoyama* and *Leyva*.<sup>22</sup>

The District Court therefore did not err.

## CONCLUSION

For the foregoing reasons, this Court should affirm the District Court's grant of class certification.

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<sup>22</sup> See, e.g., *Castillo v. Johnson*, 853 F. App'x 125, 126 (9th Cir. 2021); *Sali*, 909 F.3d at 1011; *Yokoyama*, 594 F.3d at 1094 (The “amount of damages is invariably an individual question and does not defeat class action treatment” (quotations omitted)); *Campbell v. City of L.A.*, 903 F.3d 1090, 1117 (9th Cir. 2018); *Perez v. Alta-Dena Certified Dairy, LLC*, 741 F. App'x 365, 366 (9th Cir. 2018) (“Although individual damages calculations will invariably be required, they do not defeat a finding of predominance.”); *Just Film*, 847 F.3d at 1120-21; *Ruiz Torres v. Mercer Canyons Inc.*, 835 F.3d 1125, 1136 (9th Cir. 2016) (“The presence of individualized damages calculations, however, does not defeat predominance.”); *Wright v. Renzenberger, Inc.*, 656 F. App'x 835, 839 (9th Cir. 2016); *Vaquero v. Ashley Furniture Indus., Inc.*, 824 F.3d 1150, 1155 (9th Cir. 2016) (“We have repeatedly confirmed the *Yokoyama* holding that the need for individualized findings as to the amount of damages does not defeat class certification.”); *Pulaski & Middleman, LLC v. Google, Inc.*, 802 F.3d 979, 986-88 (9th Cir. 2015) (reaffirming at length that “damage calculations alone cannot defeat class certification”); *Edwards v. Ford Motor Co.*, 603 F. App'x 538, 541 (9th Cir. 2015) (“But the need for an individual determination of damages does not, by itself, defeat class certification.”); *Jimenez v. Allstate Ins. Co.*, 765 F.3d 1161, 1167 (9th Cir. 2014); *Yokoyama*, 594 F.3d at 1094 (“[D]amage calculations alone cannot defeat certification.”).

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# Appendix

# A



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THIRD-DEGREE PRICE DISCRIMINATION AND CONSUMER SURPLUS

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## THIRD-DEGREE PRICE DISCRIMINATION AND CONSUMER SURPLUS\*

SIMON COWAN<sup>†</sup>

This paper considers the effects of monopoly third-degree price discrimination on aggregate consumer surplus. Discrimination is likely to reduce surplus (relative to that obtained with a uniform price), but surplus can rise under reasonable conditions. If the ratio of the pass-through coefficient to the price elasticity at the uniform price is higher in the market with the higher price elasticity then surplus is larger with discrimination (for a large set of demand functions). The relatively high pass-through coefficient implies a large price reduction in this market. With logit demand functions surplus is higher with discrimination if pass-through is above 0.5.

### I. INTRODUCTION

THIS PAPER CONSIDERS THE EFFECT OF MONOPOLY third-degree price discrimination (compared to uniform pricing) on aggregate consumer surplus. Third-degree price discrimination is probably the commonest form of direct discrimination. The firm uses an exogenous signal to classify customers into separate markets, and sets monopoly prices that differ across the markets. Alternatively, the firm may be constrained by policy or arbitrage to set the same price across markets. Total welfare, defined as the sum of consumer surplus and profits, with discrimination may be above or below that obtained with the uniform price. There are several reasons to consider the effect on consumer surplus on its own. Anti-trust agencies sometimes use consumer surplus, rather than total welfare, as the standard (see Farrell and Katz [2006], for a discussion). The monopolist might be owned by foreigners, so its profits would normally be excluded from the measure of domestic welfare. Consumer organizations have a natural interest in the effect of discrimination. If discrimination can be shown to raise aggregate consumer surplus then there is a strong presumption in its favour, because this ensures that total welfare will rise.

The effect of discrimination on consumer surplus is analyzed using a standard model. There are two markets, each of which is served with a

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positive quantity when there is no discrimination. When discrimination is allowed, or becomes feasible, the price rises in one market and falls in the other. One result is immediate. If discrimination reduces total welfare then consumer surplus must fall (since profits increase). It is natural to expect that discrimination will usually reduce consumer surplus. Total welfare falls if output does not increase (Schmalensee [1981] and Varian [1985]). Pigou [1920] proved that with linear demand functions, total output is the same with and without discrimination, so discrimination reduces total welfare in this case. Aguirre, Cowan and Vickers [2010] prove that, for a large class of demand functions, welfare with discrimination is lower if, at the non-discriminatory price, demand is at least as convex in the market with the lower price-elasticity. A special case is when both demand functions are linear.

The price changes induced by discrimination are modelled as if the firm faced separate cost shifts in each market. The cost pass-through coefficient—the rate at which the monopoly price changes with marginal cost—plays a central role. Pass-through is extensively analyzed by Weyl and Fabinger [2011] and is shown to be a unifying concept for many topics in industrial organization. In most of the paper, pass-through is assumed not to increase rapidly (this applies rather generally), and this yields upper and lower bounds for the change in consumer surplus. The emphasis is on finding conditions that depend, as much as possible, on observables or on general features of demand functions.

The main result is a positive one. Aggregate consumer surplus is higher with discrimination if the ratio of pass-through to the price elasticity (at the uniform price) is the same or larger in the high-elasticity market. The high-elasticity market is the one where the price falls once discrimination becomes feasible. The role of the pass-through coefficient is intuitive: high pass-through entails a large price reduction, which is good for consumer surplus. A striking application is that discrimination always increases surplus for logit demand functions whose pass-through rates exceed 0.5 (so demand is convex).

In Section 2, the model of pricing with and without discrimination is presented and cost pass-through is introduced. Section 3 shows that price changes can be modelled as if the firm faced cost shifts and derives the bounds on the change in consumer surplus. Section 4 applies the analysis to families of demands, and to specific demand functions, to show when surplus is higher with discrimination. Section 5 considers estimation issues and discusses alternative bounds. Conclusions are in Section 6.

## II. MONOPOLY PRICING

Direct utility functions are quasi-linear. Consumer surplus in a market, as a function of the price,  $p$ , is  $v(p)$ . There are two markets, labelled initially 1

and 2. (Market subscripts are used only when necessary.) With quasi-linear utility, Roy's identity implies that  $v'(p) = -q(p)$ , where  $q(p)$  is the direct demand function. At the margin, a price increase reduces surplus by the additional cost of buying the original quantity. Demand is twice-differentiable, strictly decreasing in the price (so  $v(p)$  is strictly convex) and independent of the price in the other market. Inverse demand is  $p(q)$ . The price elasticity of demand is  $\eta(q) = -\frac{p}{p'(q)q}$ . Inverse demand curvature, defined as the elasticity of the slope of inverse demand, is  $\sigma(q) = -\frac{qp''(q)}{p'(q)}$ . Curvature is positive when demand is strictly convex. Marginal revenue,  $MR(q) = p(q) + p'(q)q$ , is strictly decreasing in output, which holds if and only if  $2 - \sigma > 0$ . Demand must not be too convex.

Marginal cost,  $c$ , is constant and non-negative. The unique discriminatory quantity,  $q^*$ , is determined by  $MR(q^*) = p(q^*) + p'(q^*)q^* = c$  and the associated monopoly price (which depends on marginal cost) is  $P(c) \equiv p(q^*)$ . Discriminatory prices differ across the markets. Differentiating the first-order condition gives the cost pass-through coefficient as  $P'(c) = p'(q^*) \frac{dq^*}{dc} = \frac{1}{2 - \sigma(q^*)}$ , which is the ratio of the slope of inverse demand to the slope of marginal revenue.<sup>1</sup> Pass-through is positive and is higher the more convex demand is. It is usually more convenient to work with pass-through rather than demand curvature.

Four illustrative demand functions will be used. For linear demand, pass-through is 0.5 since  $\sigma = 0$ . With exponential demand,  $q(p) = Ae^{-\frac{p}{b}}$ , the monopoly price is  $P(c) = c + b$  and pass-through is 1. Constant-elasticity demand,  $q(p) = Ap^{-\eta}$  for  $\eta > 1$ , implies that  $P(c) = \frac{\eta c}{\eta - 1}$  with pass-through of  $\frac{\eta}{\eta - 1} > 1$ . In this case as  $\eta$  falls towards 1 from above pass-through rises rapidly. For the logit demand function,  $q(p) = (1 + e^{p-a})^{-1}$ , pass-through is  $1 - q^*$ , which is increasing in  $c$  since the monopoly quantity falls as marginal cost rises (see Appendix One).

Define  $\frac{P(c)P''(c)}{[P'(c)]^2}$  as the curvature of the monopoly price in marginal cost, which measures how rapidly pass-through increases. The key assumption, which will be applied in the next section, is that pass-through does not increase too quickly.

*The Pass-Through Assumption.* The price elasticity of demand is higher than the curvature of the monopoly price in marginal cost.

This holds for many standard demand functions. If pass-through is constant or decreasing, then  $P''(c) \leq 0$  and the assumption certainly holds. Constant pass-through demand functions are commonly used in industrial organization, and the linear, exponential and constant-elasticity functions are examples. The single-commodity AIDS demand function has

<sup>1</sup> See Bulow and Pfleiderer [1983] for an early analysis of pass-through.

decreasing pass-through (Weyl and Fabinger [2009]). The assumption may also hold when pass-through is increasing. It holds for the logit if and only if pass-through exceeds 0.5, which is when  $p > a$  and demand is strictly convex—see Appendix One.<sup>2</sup>

Profit in market  $i \in \{1, 2\}$ , as a function of price, is  $\pi_i(p_i) = (p_i - c)q_i(p_i)$ . The non-discriminatory (or uniform) price,  $\bar{p}$ , maximizes aggregate profit,  $\pi_1(p) + \pi_2(p)$ , and is characterized by the first-order condition<sup>3</sup>

$$(1) \quad \pi'_1(\bar{p}) + \pi'_2(\bar{p}) = 0.$$

Assume that at this price both markets are served with positive quantities, so  $\bar{q}_i \equiv q_i(\bar{p}) > 0$  for both  $i$ . A new market is not opened by price discrimination. Equation (1) says that the marginal profitabilities are of equal size and opposite sign, and this fact will be used in the derivation of the bounds. Marginal profitability is related to the gap between marginal revenue and marginal cost by

$$(2) \quad \pi'_i(p_i) = (MR_i(q_i) - c)q'_i(p_i).$$

Without discrimination marginal revenue exceeds marginal cost in one market and is below marginal cost in the other market. Following Joan Robinson [1933] the market with the higher marginal revenue, where the price falls with discrimination, is called the ‘weak’ market, and the market where the price rises is ‘strong.’ The subscripts  $w$  and  $s$  are used to denote the weak and strong markets respectively, with prices satisfying  $P_w(c) < \bar{p} < P_s(c)$  and marginal revenues satisfying  $MR_w(\bar{q}_w) > c > MR_s(\bar{q}_s)$ . To identify the weak and strong markets at the non-discriminatory price the textbook relationship between marginal revenue, price and the elasticity,  $MR_i(\bar{q}_i) = \bar{p}\left(1 - \frac{1}{\eta_i(\bar{q}_i)}\right)$ , can be used. The weak market has higher marginal revenue and so has the higher elasticity at the non-discriminatory price.

### III. BOUNDING THE CHANGE IN CONSUMER SURPLUS

There are three steps in the analysis. First, the problem is converted to an equivalent one involving cost shifts. Second, consumer surplus is shown to

<sup>2</sup> The pass-through assumption also holds for demands derived from the normal distribution (when convex), and demand from the Weibull distribution,  $q = e^{-p^\gamma}$ , provided  $\gamma \geq 1$  (which implies that pass-through is no greater than 1).

<sup>3</sup> Equation (1) holds at the optimum even if the aggregate profit function has multiple peaks (which may happen if demand functions are convex). Each market’s profit function is single-peaked in the price when marginal revenue is decreasing so, by Theorem 1 of Nahata, Ostaszewski and Sahoo [1990], the non-discriminatory price lies in between the two discriminatory prices.

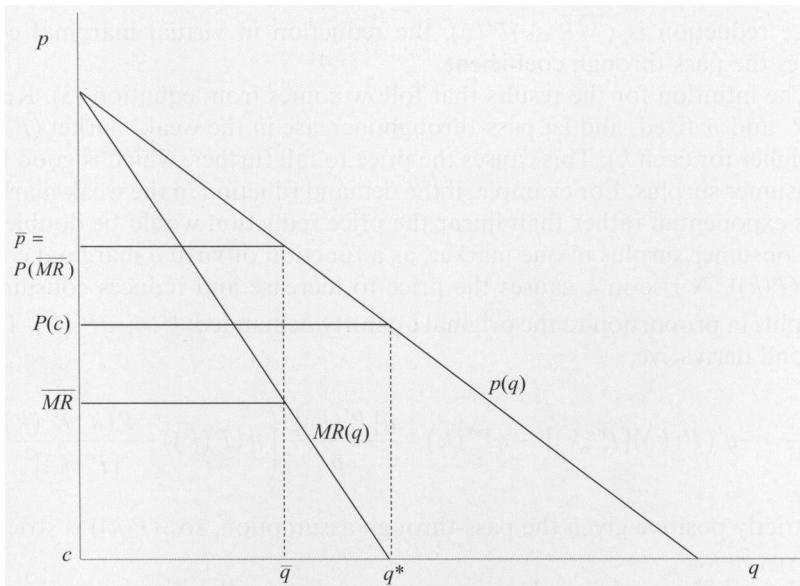


Figure 1  
The Uniform Price is the Monopoly Price when Marginal Cost Equals  $\overline{MR}$

be convex in marginal cost (given monopoly pricing) if the pass-through assumption holds. Third, the implications of profit-maximization are combined with the convexity of surplus to obtain the bounds.

To see why the problem is equivalent to one with cost shifts consider Figure 1. This illustrates the weak market, whose discriminatory price (determined by the quantity at which marginal revenue equals marginal cost) is below the non-discriminatory price. When would  $\bar{p}$  be a monopoly or profit-maximizing price for this market? The answer is that if marginal cost equalled  $\overline{MR} \equiv MR(\bar{q})$  then  $\bar{p}$  would maximize profit. The non-discriminatory price equals the monopoly price that would be set if marginal cost were  $\overline{MR}$ , i.e.,  $P(\overline{MR}) \equiv \bar{p}$ .

The reduction in price caused by discrimination equals that of a profit-maximizing monopolist whose marginal cost falls from  $MR$  to  $c$ . This device allows the price reduction to be written as the integral of the pass-through coefficients:

$$(3) \quad P(\overline{MR}) - P(c) = \int_c^{\overline{MR}} P'(k) dk$$

where  $k$  is the variable of integration and is interpreted as virtual marginal cost. This equation applies in each market. With constant pass-through, the

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price reduction is  $(\overline{MR} - c)P'(c)$ , the reduction in virtual marginal cost times the pass-through coefficient.

The intuition for the results that follow comes from equation (3). Keep  $\overline{MR}$  and  $\bar{p}$  fixed, and let pass-through increase in the weak market ( $P'(k)$  is higher for each  $k$ ). This causes the price to fall further, which is good for consumer surplus. For example, if the demand function in the weak market was exponential rather than linear the price reduction would be doubled.

Consumer surplus in one market, as a function of virtual marginal cost, is  $v(P(k))$ . A rise in  $k$  causes the price to increase and reduces consumer surplus in proportion to the original quantity demanded:  $\frac{dv}{dk} = -qP'(k)$ . The second derivative,

$$\frac{d^2v}{dk^2} = -q'(P(k))[P'(k)]^2 - qP''(k) = \frac{q[P'(k)]^2}{p} \left( \eta(P(k)) - \frac{P(k)P''(k)}{[P'(k)]^2} \right),$$

is strictly positive given the pass-through assumption, so  $v(P(k))$  is strictly convex in  $k$ .

The change in surplus in one market with discrimination is  $v(P(c)) - v(P(\overline{MR})) \equiv \Delta v$ . The derivative of surplus with respect to  $k$ , evaluated at  $\overline{MR}$ , is  $-\bar{q}P'(\overline{MR})$ . A strictly convex function lies above its tangents, so the change in surplus exceeds this derivative multiplied by the change in  $k$ , i.e.,  $\Delta v > (\overline{MR} - c)P'(\overline{MR})\bar{q}$ . This lower bound is the first-order approximation to the price reduction multiplied by the quantity purchased at the uniform price. The upper bound uses the tangency at  $c$ . Adding across the markets the bounds for the change in total consumer surplus,  $\Delta V$ , are

$$(4) \quad \sum_i (\overline{MR}_i - c)P'_i(c)q_i^* > \Delta V > \sum_i (\overline{MR}_i - c)P'_i(\overline{MR}_i)\bar{q}_i.$$

The bounds in (4) are now re-written using equation (2), the fact that  $-\frac{\bar{q}_i}{q'_i(\bar{p})} = \frac{\bar{p}}{\eta_i(\bar{q}_i)}$  for the lower bound and, for the upper bound,  $q_i^* = -(P_i(c) - c)q'_i(P_i(c))$  from the first-order condition. The resulting bounds are:

$$(5) \quad \sum_i [-\pi'_i(\bar{p})](P_i(c) - c)P'_i(c) \frac{q'_i(P_i(c))}{q'_i(\bar{p})} > \Delta V > \sum_i [-\pi'_i(\bar{p})]\bar{p} \frac{P'_i(\overline{MR}_i)}{\eta_i(\bar{q}_i)}.$$

Applying the consequences of profit-maximization at the non-discriminatory price, characterized in (1), yields the main result.

*Proposition 1.* Given the pass-through assumption: (i) Consumer surplus is higher with discrimination if the ratio of pass-through to the price

elasticity at the non-discriminatory quantity,  $\frac{P'_i(\bar{M}\bar{R}_i)}{\eta_i(\bar{q}_i)}$ , is at least as high in the weak market as in the strong market; (ii) Consumer surplus is lower with discrimination if  $(P_s(c)-c)P'_s(c)\frac{q'_s(P_s(c))}{q'_s(\bar{p})} \geq (P_w(c)-c)P'_w(c)\frac{q'_w(P_w(c))}{q'_w(\bar{p})}$ .

*Proof.* (i) Because  $\pi'_s(\bar{p}) = -\pi'_w(\bar{p}) > 0$  by (1), and  $\bar{p}$  can be taken outside the summation sign, the lower bound in (5) has the sign of  $\frac{P'_w(\bar{M}\bar{R}_w)}{\eta_w(\bar{q}_w)} - \frac{P'_s(\bar{M}\bar{R}_s)}{\eta_s(\bar{q}_s)}$ , which is non-negative under the stated condition. Similarly the upper bound is non-positive if the condition in (ii) holds.

The condition that is sufficient for surplus to fall, given in (ii), is considered first. This depends on the discriminatory margins and pass-throughs, and the ratio of the demand slopes at the two prices, and thus has a large information requirement. With linear demand, pass-through is 0.5 and the ratio of the demand slopes is 1. Since, by definition, the discriminatory margin  $P_i(c) - c$  is higher in the strong market, the inequality in Proposition 1(ii) holds strictly if both demand functions are linear. This can be generalized. With concave demand functions in each market  $\frac{q'_s(P_s(c))}{q'_s(\bar{p})} \geq 1 \geq \frac{q'_w(P_w(c))}{q'_w(\bar{p})}$ . Define the pass-through-adjusted margin as  $(P_i(c) - c)P'_i(c)$ . If (a) the demand functions are concave and (b) the pass-through-adjusted margin is the same or higher in the strong market, then (ii) holds. If the two demand functions are concave and have the same pass-through (or there is lower pass-through in the weak market) then this itself entails (b).

If both demands are convex and the pass-through-adjusted margin is at least as high in the weak market, then condition (ii) does not hold, so surplus may be higher with discrimination. In a loose sense it is more likely that surplus is higher with discrimination when all demands are convex than when they are all concave. Pass-through is at most 0.5 with concave demand but may be much higher with convex demand, allowing for a large price reduction in the weak market.<sup>4</sup>

The sufficient condition for surplus to be higher with discrimination is given in part (i) of Proposition 1. It holds only if pass-through and the elasticity are positively correlated.<sup>5</sup> The condition is testable empirically if the elasticities and pass-throughs can be estimated. Perhaps surprisingly, a local condition at the non-discriminatory price is sufficient for surplus to rise, provided that demand functions are in the class that satisfies the

<sup>4</sup> Similarly Malueg [1993] shows that concavity of demand places an upper bound on the proportional welfare gain from discrimination, while the welfare gain can be unbounded when demand is convex.

<sup>5</sup> Thus the condition does not hold if both demands have constant elasticities. For this case, Ippolito [1980] shows by numerical analysis that discriminatory consumer surplus can be higher, but usually is lower, than surplus at the uniform price.

pass-through assumption. Knowledge of the discriminatory prices and quantities is not needed. The condition is now put to work.

#### IV. APPLICATIONS

Three applications of the condition for surplus to be higher with discrimination are given. The first is when demand functions are logits. The second is an example that uses local information when there is no discrimination. The third shows that sometimes Proposition 1 can also be used when the starting point is the discriminatory outcome.

##### IV(i). *Logit Demands with Pass-Through above 0.5*

Surplus is always higher with discrimination when both demand functions are logits with pass-through above 0.5. Demand in market  $i$  is  $q_i(p_i) = N_i(1 + e^{(p_i - a_i)})^{-1}$  where  $N_i$  is the number of potential consumers, each of whom buys one unit of the good if and only if their valuation exceeds the price. Valuations in market  $i$  have a logistic distribution with mean  $a_i$ . The strong market has the higher mean, while the variances are the same in the two markets. The logistic distribution has slightly more weight in its tails than a normal distribution.<sup>6</sup> Without loss of generality  $N_i$  can be normalized to 1. Inverse demand is  $p_i(q_i) = a_i - \ln\left(\frac{q_i}{1-q_i}\right)$ , which is the mean less the log-odds ratio. Demand is convex when price is above the mean and concave for lower prices.

The logit's pass-through coefficient is  $1 - q_i$  and its price elasticity is  $p_i(1 - q_i)$  (see Appendix One). Thus the ratio of pass-through to the elasticity is  $\frac{1}{p_i}$ , and at the uniform price the ratios are equal, so the condition in Proposition 1(i) holds exactly. The pass-through assumption holds for the logit when pass-through exceeds 0.5, which is in the convex region of demand where  $p_i > a_i$  and  $q_i < 0.5$ . In turn, a sufficient (but by no means necessary) condition for  $p_i > a_i$  is that the mean valuations are bounded above by marginal cost,  $c \geq a_s > a_w$ , since all prices exceed  $c$ . Thus the shape of the demand function and the assumption that the mean valuations are no higher than marginal cost together imply that consumer surplus is higher with discrimination. The non-discriminatory price does not need to be known, and all markets are automatically served at this price because logit demand is always positive.

Can this result be generalized? The demand function, written in general as  $q(p - a)$ , needs three properties: (i) the pass-through assumption must hold; (ii) the price elasticity, at a given price, should fall as  $a$  increases so

<sup>6</sup> See Anderson, de Palma and Thisse [1992] for an analysis of the logit model.

that the market with the higher  $a$  is the strong one; (iii) the pass-through-elasticity ratio should not rise as  $a$  increases (for a given price). Property (ii) applies if and only if pass-through is strictly below 1, which holds for linear demand but not for exponential or constant-elasticity demand.<sup>7</sup> Property (iii) holds for the exponential and constant-elasticity functions, but not for linear demand. One demand function, in addition to the logit, has all three properties. This is demand based on the Extreme Value distribution (provided the price exceeds the mean)—see Appendix Two. This distribution is closely related to the logistic and has slightly fatter tails. The set of demand functions whose shape alone implies that surplus is higher with discrimination is small. The surprise, perhaps, is that it is non-empty.

#### IV(ii). *An Example Using Information at the Uniform Price*

Local knowledge of pass-through coefficients and elasticities is usually needed to apply Proposition 1. Suppose that the weak market has a constant elasticity of  $\eta_w > 1$  (and thus pass-through of  $\frac{\eta_w}{\eta_w - 1}$ ) and demand in the strong market is linear with pass-through of  $\frac{1}{2}$ . Both demand functions satisfy the pass-through assumption. The markets are appropriately classified as weak and strong if  $\eta_w > \eta_s(\bar{q}_s)$ . The pass-through-elasticity ratios are  $\frac{1}{\eta_w - 1}$  in the weak market and  $\frac{1}{2\eta_s(\bar{q}_s)}$  in the strong market. Thus Proposition 1(i) applies if  $\eta_s(\bar{q}_s) \geq \frac{\eta_w - 1}{2}$ . Application of the condition requires knowledge of the pass-through rates and elasticities, but marginal cost and the relative sizes of the markets do not need to be known. What matters is information about the shapes of the demand functions.

#### IV(iii). *When Does a Move to a Uniform Price Reduce Consumer Surplus?*

Suppose the firm currently sets the discriminatory prices. What would be the effect on consumers of a move to uniform pricing? Here it is shown that if two conditions both hold then Proposition 1(i) applies and a move away from discrimination would reduce surplus. Condition (a) is that the pass-through-adjusted margin (defined in Section 3) is at least as high in the weak market:  $(P_w(c) - c)P'_w(c) \geq (P_s(c) - c)P'_s(c)$ . Aguirre, Cowan and Vickers [2010, Proposition 2] show that, with some additional assumptions, this implies that total welfare is higher with discrimination. Condition (b) is that  $\frac{d}{dq}[(p(q) - MR(q))P'(MR)] \leq 0$ , so the gap between price and marginal revenue, adjusted for the local pass-through coefficient, is non-increasing in quantity. If both conditions hold then

<sup>7</sup> Note that  $-q'(p - a)/q(p - a)$  rises with  $p$  (and thus falls with  $a$ ) when  $\sigma < 1$  and pass-through is below 1.

$$\begin{aligned}
 (\bar{p} - \overline{MR}_w)P'_w(\overline{MR}_w) &\geq (P_w(c) - c)P'_w(c) \\
 &\geq (P_s(c) - c)P'_s(c) \\
 &\geq (\bar{p} - \overline{MR}_s)P'_s(\overline{MR}_s).
 \end{aligned}$$

The first and last inequalities are by (b), while the middle inequality states condition (a). Since  $\bar{p} - \overline{MR}_i = \frac{\bar{p}}{\eta_i(\bar{q}_i)}$  the chain of inequalities implies that Proposition 1(i) holds (provided the pass-through assumption applies). The logit, exponential and constant-elasticity functions all satisfy (b).<sup>8</sup> Condition (b) does not hold for linear demand or, more generally, for demand with constant pass-through below 1.

For example, let demand in the weak market have a constant elasticity,  $\eta_w$ , with margin  $P_w(c) - c = \frac{c}{\eta_w - 1}$  and pass-through-adjusted margin  $\frac{c\eta_w}{(\eta_w - 1)^2}$ . The strong market has exponential demand, so both the margin and the pass-through-adjusted margin equal  $b$ , which must be above  $\frac{c}{\eta_w - 1}$  for the markets to be correctly labelled as weak and strong. Surplus is then higher with discrimination if  $\frac{c\eta_w}{(\eta_w - 1)^2} \geq b$ . In well-defined (though rather special) circumstances surplus can be shown to be higher with discrimination when the starting point is discrimination. The non-discriminatory price and the relative market sizes do not need to be known in order to show this.

## V. ESTIMATION AND EXTENSIONS

This section discusses how to estimate pass-through coefficients and alternative bounds that can be used when Proposition 1 does not work.

### V(i). Estimating Cost Pass-Through

How might pass-through rates be estimated? The following discussion expands on that in Aguirre, Cowan and Vickers [2010, p. 1607]. First, suppose that the starting point is discrimination and that pass-through can be assumed to be constant. It follows that the monopoly price is an affine function of marginal cost and the estimated pass-through rate is the slope coefficient in a reduced-form regression of price on marginal cost. In principle, this could be done for each market. This requires sufficient variation in marginal cost and in prices to be feasible, but it does not require data on

<sup>8</sup> The logit has  $p - MR = \frac{1}{1-q}$  and pass-through of  $1-q$ , so  $(p - MR)P'(MR) = 1$ . With exponential demand  $(p - MR)P'(MR) = b$ . Constant-elasticity demand has  $(p - MR)P'(MR) = \frac{p(q)}{\eta - 1}$ , which falls as  $q$  increases. Condition (b) is equivalent to property (iii) in Section 4.1.

quantities. Second, suppose that currently there is uniform pricing. The demand functions would have to be estimated using data on quantity and price in each market. In oligopoly contexts Genesove and Mullin [1998], and Clay and Troesken [2003], estimate four demand functions with constant pass-throughs: the linear, exponential and constant-elasticity functions, plus demand with pass-through of  $\frac{2}{3}$ . In a recent paper on intertemporal price discrimination Hendel and Nevo [2011] estimate an exponential demand function. There is no reason, in principle, to restrict attention to constant pass-through demand functions. Other demand functions, such as logits and probits, can be estimated. The main point is that once the demand specification has been determined and the parameters estimated the pass-through rate follows immediately. The problem of estimating pass-through is the same as that of estimating the demand function.

#### V(ii). Additional Bounds

Proposition 1 does not always yield results. It may be that the opposite of the pass-through assumption holds, so the price elasticity is always below the curvature of the monopoly price in marginal cost. This happens with logit demands if pass-through is below 0.5. Surplus is then concave in marginal cost and the bounds in (5) are reversed. The weighted sum of the pass-through-elasticity ratios becomes the upper bound. With logits this weighted sum is zero, so surplus falls with discrimination. Pass-through is below 0.5 when the demand means are sufficiently high relative to marginal cost that in each market all prices are below the demand mean.

Alternatively there may be agnosticism about the pass-through assumption, or it might apply but neither sufficient condition in Proposition 1 is satisfied. Suppose that prices and quantities with and without discrimination are all observed. The weak assumption that demand is downward-sloping alone implies that consumer surplus is strictly convex in prices. A given price cut causes surplus to rise by more than the loss caused by an equivalent price increase. With strict convexity the change in aggregate surplus has the following bounds,  $\sum_i (\bar{p} - p_i(q_i^*))q_i^* > \Delta V > \sum_i (\bar{p} - p_i(q_i^*))\bar{q}_i$ , which formed the basis of the welfare analysis of Varian [1985]. The upper bound is negative if average revenue with discrimination,  $\sum p_i(q_i^*)q_i^*/\sum q_i^*$ , exceeds the uniform price. The lower bound is positive if it costs less to buy the non-discriminatory quantities at the discriminatory prices than at the uniform price. These bounds would not be helpful if starting at, say, the uniform price a prediction of the effect of a move to discrimination is required. If the information necessary to determine the discriminatory prices and quantities were available, then the effect on surplus could be calculated directly (and this would always give an answer, whereas the bounds sometimes do not). But the bounds may be useful if

achange has happened and prices and quantities before and after are observed.

## VI. CONCLUSION

This paper has shown that discrimination can be good for consumers in aggregate under reasonable conditions. The conditions are potentially testable and do not rely on unusual features of demand functions. Surplus will, though, often be lower with discrimination. Treating a discrete change in price as if it were caused by a shift in a monopolist's marginal cost proved to be a useful analytical device and may have other applications. The logit example is striking and clear, and shows the value of using demand functions derived from statistical distributions. A natural extension is to consider the effect of discrimination on both welfare and surplus in an oligopoly whose demand structure has a multinomial logit form.

## APPENDIX ONE: LOGIT DEMAND

This appendix presents the expressions for pass-through and the price elasticity for the logit demand, and shows that the pass-through assumption holds if and only if pass-through exceeds 0.5. The logit demand function is  $q(p) = (1 + e^{p-a})^{-1} \in (0, 1)$ . (Without loss of generality, the multiplicative market-size parameter  $N$  is normalized to unity.) Inverse demand is  $p(q) = a - \ln\left(\frac{q}{1-q}\right)$ , with slope  $p'(q) = -\frac{1}{q(1-q)}$  and second derivative  $p''(q) = \frac{1-2q}{[q(1-q)]^2}$ . Inverse demand curvature is  $\sigma(q) \equiv -\frac{qp''}{p'} = \frac{1-2q}{1-q}$ , and pass-through is  $\frac{1}{2-\sigma} = 1-q$ . The price elasticity is  $\eta \equiv -\frac{p}{p'(q)q} = p(1-q)$ . Pass-through, as a function of marginal cost, is  $P'(c) = 1 - q(P(c))$ . The slope of pass-through is  $P''(c) = -q'(P(c))P'(c) = q(1-q)^2 > 0$ , using  $q'(p) = 1/p'(q)$ , so pass-through is strictly increasing. It follows that  $\eta - \frac{P(c)P'(c)}{[P'(c)]^2} = p[1-2q]$  is positive, i.e., the pass-through assumption holds, if and only if  $q < 0.5$ . When  $q < 0.5$  pass-through exceeds 0.5, demand is strictly convex and  $p > a$ . When  $q > 0.5$  the opposite of the pass-through assumption holds.

## APPENDIX TWO: THE TYPE 1 EXTREME VALUE DISTRIBUTION

Demand derived from the Type 1 Extreme Value distribution is  $q(p) = 1 - e^{-e^{a-p}}$ , with  $q'(p) = -e^{a-p}(1-q)$  and  $q''(p) = e^{a-p}(1 - e^{a-p})(1-q)$ . The Type 1 Extreme Value is a strictly log-concave distribution which implies that  $\sigma < 1$  (see Bagnoli and Bergstrom [2005]) so property (ii) in Section 4.3 holds. Property (iii) can be shown numerically to hold everywhere: the pass-through-elasticity ratio falls as  $a$  rises. Finally the pass-through assumption–property (i)–can also be shown by numerical analysis to hold if the price exceeds the mean of the distribution, which is  $a + \gamma$  where  $\gamma \approx 0.5772$  is the Euler-Mascheroni constant. Thus, in common with the logit, if the price is above the mean the condition in Proposition 1(i) holds.

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# **Appendix B**

## CARTEL DAMAGES CLAIMS AND THE PASSING-ON DEFENSE\*

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We develop a general framework for computing cartel damages claims. We decompose a direct purchaser plaintiff's lost profits in three parts: the price overcharge, the pass-on effect and the output effect. The output effect is usually neglected: it is the lost business resulting from passing on the price overcharge. To evaluate the relative importance of the three effects, we introduce various models of imperfect competition for the plaintiff's industry. We show that the passing-on defense generally remains justified after accounting for the output effect, provided that the cartel affects a sufficient number of firms. We derive exact discounts to the price overcharge, and illustrate how to compute these in the European vitamin cartel. We finally extend our framework to measure the cartel's total harm, i.e., the total damages to direct purchasers and their consumers.

### I. INTRODUCTION

THE ANTICOMPETITIVE PRICE OVERCHARGE HAS BEEN COMMONLY USED as a basis for computing damages claims in price-fixing cartels. There is, however, an ongoing debate as to whether the cartel members may resort to a passing-on defense. Such a defense entails the argument that the purchaser plaintiff may have passed on part of the cartel's price overcharge to its own customers and correspondingly suffered lower losses than the overcharge. In both the U.S. and Europe there has recently been a renewed interest in properly assessing cartel damages, including the possible consideration of the passing-on defense.<sup>1</sup>

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<sup>1</sup>The U.S. Antitrust Modernization Commission [2007] has recently recommended making cartel damages claims in line with lost profits, implying the possibility of a passing-on defense (although there was no consensus on this recommendation, see Commissioner Dennis Carlton [2007]). The European Commission [2005] issued a Green Paper on private cartel damages and

Against this background we develop a general economic framework for computing cartel damages. We focus on a direct purchaser plaintiff's lost profits, but we also apply our approach to consider the cartel's total harm (the sum of damages to direct purchasers and their consumers). We decompose the direct purchaser plaintiff's lost profits from the cartel into three effects. First, the price overcharge or cost effect is the extra price the plaintiff has to pay for the cartelized input. Second, the pass-on effect reflects the extent to which the purchaser plaintiff can shift the burden of the price overcharge to its own customers. Third, the usually neglected output effect refers to the sales that are lost when part of the price overcharge is passed on to the customers.

We then introduce various models of imperfect competition to describe the downstream industry in which the purchaser plaintiff operates. This enables us to evaluate the relative importance of the three effects from the cartel. Consistent with common practice, we take the price overcharge (or cost effect) as the basis for computing damages and show how to compute a discount to this overcharge. This discount captures the pass-on effect, but suitably adjusted for the output effect. We first consider the case of a common cost increase, in which all competitors in the plaintiff's industry are affected by the cartel. We show that in this case the discount to the price overcharge is generally positive, unless the plaintiff operates itself in a fully cartelized downstream industry. This motivates an adjusted passing-on defense, where the adjustment factor reflects the output effect and depends on the intensity of competition, as illustrated for Bertrand or Cournot industries.

We next consider the case of a firm-specific cost increase, in which not necessarily all of the plaintiff's competitors are affected by the cartel. This is relevant in several circumstances, for example when some of the cartel members are vertically integrated and do not overcharge their own downstream units. In this case the output effect becomes more important, because the plaintiff may now also lose business to its unaffected competitors within the industry, in addition to losing business outside the industry. We show that an adjusted passing-on defense remains economically justified in a Bertrand industry. In a Cournot industry, however, the passing-on defense becomes invalid if there are sufficiently many unaffected competitors, since these respond expansively to the output contractions of the plaintiff and other affected firms. For both the Bertrand and the Cournot models, we derive exact discounts to the price overcharge when the adjusted passing-on defense is justified. These discounts are easy to interpret and depend on observable variables for the plaintiff's industry, such as the

the possibility of a passing-on defense. We review these developments against the history of previous case law in section 2.

pass-on rate, the total number of firms, the number of firms affected by the cartel, the plaintiff's and/or the other firms' market shares.

To illustrate our results, we apply an adjusted passing-on defense to the European vitamin cartel of 1989–1999. We show how to compute discounts to the price overcharge that is based on information from the public domain. In particular, we require the following information for the plaintiff's downstream industry: the total number of firms, the number of firms affected by the cartel and the market shares of the plaintiffs and their competitors. In this application we find that the price overcharge should be discounted by a quite large amount, even after adjusting for the output effect.

Most previous research has focused on the law and economics of the passing-on defense, providing informational and incentive arguments for or against the use of a passing-on defense in cartel damages cases.<sup>2</sup> We instead focus on measuring the economic effects and stress the essential importance of the output effect whenever the passing-on defense is considered. To our knowledge there are only a few papers that explicitly elaborate on the output effect (or ‘lost business’ effect), i.e., Kosicki and Cahill [2006] and Hellwig [2006]. These papers focus on the case in which the plaintiff's industry is itself fully cartelized (so that the passing-on defense becomes invalid), or consider some other special cases with graphical or numerical analysis. In contrast, we identify the role of the output effect in a wide variety of oligopoly industries, and account for the possibility that some of the plaintiff's competitors are not affected by the cartel. Furthermore, we pin down the precise informational requirements in implementing an adjusted passing-on defense: in addition to estimating the degree of pass-on as in a traditional passing-on defense, one essentially also needs to measure the extent of market power in the plaintiff's downstream industry.

We obtain these results based on a simple differential approach, which looks at the effects of a ‘small’ price overcharge. This approach has the advantage of clarifying the economic role of the output effect in a general framework. It ignores, however, second-order effects which may become important for large price overcharges. To assess the effects of large overcharges one could apply ‘simulation analysis,’ as is done in other areas of antitrust such as merger analysis (e.g., Werden and Froeb [1994]).

Our analysis largely focuses on the cartel damages to a direct purchaser plaintiff. Basso and Ross [2007] instead consider the cartel's total harm, i.e.,

<sup>2</sup> Landes and Posner [1979] advance several arguments as to why damages claims by direct purchasers without a passing-on defence are more reliable and hence have a better deterrence effect. Harris and Sullivan [1979], in contrast, argue in favour of the passing-on defense to ensure a correct damages compensation. In an interesting recent paper Schinkel *et al.* [2008] show how the cartel may have an incentive to ‘bribe’ direct purchasers not to bring damages claims if indirect purchasers cannot bring damages claims. See van Dijk and Verboven (2007) for a more detailed overview of these arguments.

the total effect on the direct purchasers and on the final purchasers. Boone and Müller [2008] look at the question of how the cartel's total harm is distributed between direct purchasers and consumers. Han, Schinkel and Tuinstra [2008] focus on the role of many downstream and upstream firms along the production chain. Inspired by these papers, we briefly extend our differential approach to assess the cartel's total harm. The pass-on effect is then only a transfer between the direct purchasers and final consumers. We show that the cartel's total harm therefore unambiguously exceeds the price overcharge by an amount equal to the output effect.<sup>3</sup> Hence, an adjusted passing-on defense against a purchaser plaintiff may actually turn against the defendant, since the evidence required to adjust the pass-on effect for the output effect may also be used to demonstrate by how much the cartel's total harm exceeds the price overcharge.

The paper is organized as follows. Section 2 reviews previous practices towards cartel damages claims and the passing-on defense. Section 3 presents the general economic framework, decomposing the plaintiff's lost profits in a cost, pass-on and output effect. Section 4 considers the case of a common cost increase (to all of the plaintiff's competitors), and section 5 the case of a firm-specific cost increase (to a subset of the plaintiff's competitors). Section 6 provides an application to the European vitamin cartel. Section 7 considers the cartel's total harm and section 8 concludes.

## II. STATE OF PLAY IN THE U.S. AND EUROPE

We briefly review the history and logic of cartel damages claims, with a focus on the passing-on defense. For a more detailed discussion, we refer to the references in this section, and the extensive literature they cite.

### *United States*

The current situation in the U.S. is the result of three major Supreme Court decisions, *Hanover Shoe*, *Illinois Brick*, and *ARC America*, and subsequent legislation by various states.<sup>4</sup> In *Hanover Shoe*, the defendant argued that the overcharged purchaser plaintiff does not suffer losses if the price overcharge is imposed equally on all of the purchaser's competitors and if the demand is so inelastic that the purchasers can pass on the overcharge without suffering a decline in sales. The Supreme Court rejected this argument on the grounds of insurmountable practical difficulties in proving

<sup>3</sup> This corresponds to Basso and Ross' [2007] result that the total harm is higher than the price overcharge. However, they do not relate this to the output effect, which emerges clearly from our framework and which suggests how to measure it practically in terms of observable variables.

<sup>4</sup> The three cases are *Hanover Shoe Inc. v. United Shoe Machinery Corp.*, 392 U.S. 481 [1968] and *Illinois Brick Co. v. Illinois*, 431 U.S. 720 [1977], and *California v. ARC America Corp.*, 490 U.S. 93 [1989].

that the purchaser indeed passed on the price overcharge and how this passing-on would affect sales. Furthermore, it considered that the indirect purchasers tend to be too dispersed and too weak to subsequently recover any damages resulting from the passing-on by the direct purchasers, implying that the cartel offenders might get off too lightly. In *Illinois Brick* the Court continued this logic and denied indirect purchasers the right to claim damages, since the *Hanover Shoe* decision already made the cartel liable for the full damages to direct purchasers.

Interestingly, Justice White, who delivered the opinion of the Court in *Illinois Brick*, points at two complicating factors in practice that are assumed away in ‘the economist’s hypothetical model’ (original wording from the *Hanover Shoe* decision): ‘Overcharged direct purchasers often sell in imperfectly competitive markets. They often compete with other sellers that have not been subject to the overcharge . . .’ (see <http://www.ripon.edu/Faculty/bowenj/antitrust/ilbrvill.htm>). Our paper deals with precisely these two factors: section 4 focuses on imperfect competition, and section 5 adds complications relating to the fact that not all competitors may be subject to the overcharge.

There was considerable opposition against *Illinois Brick* in the decade following the decision. Congress was not able to pass any bills to overturn the decision, but in *ARC America*, the Supreme Court legitimized indirect purchaser suits in state courts. Furthermore, various states have passed *Illinois Brick* repealer laws or used existing consumer protection statutes to permit indirect purchasers to bring damages claims against cartels; see Hussain, Garrett and Howell [2001]. As discussed in Kosicki and Cahill [2006] several of these states also entitled the defendant to resort to a passing-on defense against these indirect purchasers.

Under the current situation, direct purchasers can thus in principle claim the full price overcharge in federal courts (whether or not passed on). Furthermore, the indirect purchasers may obtain a duplicate part of that amount, i.e., their own lost profits, in some state courts. While there do not appear to be cases in which this has lead to an overcompensation of all parties affected by the cartel, the Antitrust Modernization Commission [2007] has recently recommended making direct and indirect purchaser damages claims more in line with their actual lost profits from the cartel. Following these recommendations would open the door for a passing-on defense, not just against the indirect but also against the direct purchasers of a cartel.

### *Europe*

In Europe the experience with private damages claims in competition law infringement cases has been rather limited. There is, however, extensive case law in other areas, for example in cases where undertakings claim restitution of illegal duties and levies from the state. As discussed in Norberg [2005], in *Comateb* the European Court of Justice accepted that a passing-on defense

was compatible with Community Law, but also clarified that the plaintiff ‘may have suffered damage as a result of the very fact that he passed on the charge . . . because the increase in price has led to a decrease in sales.’<sup>5</sup> This appears closely related to the output effect we emphasize in our analysis below.

Only recently, in *Courage* the European Court of Justice confirmed that infringements of Articles 81 and 82 of the EC Treaty provide a legal basis for bringing damages claims.<sup>6</sup> Following this decision, the European Commission put private cartel damages claims and the possible consideration of a passing-on defense as a high priority on the agenda. It requested the Ashurst study on private enforcement of competition policy in 2004.<sup>7</sup> This lead to the European Commission’s [2005] Green Paper on damages actions for breach of antitrust rules, which includes a discussion on the role of the passing-on defense. Interestingly, the Commission writes: ‘It can be said that there is no passing on defense in Community law; rather, there is an unjust enrichment defense which requires (1) proof of passing on . . . and (2) proof of no reduction in sales or other reduction to income’ (European Commission [2005], p. 48). One may interpret this unjust enrichment defense as an adjusted version of the passing-on defense, which also accounts for the additional output effect following pass-on.<sup>8</sup> Our own analysis will show how to implement such an adjusted passing-on defense in a wide variety of competitive circumstances.

### III. GENERAL ECONOMIC FRAMEWORK

This section decomposes the purchaser plaintiff’s lost profits from the cartel into three effects: the price overcharge (or cost effect), the pass-on effect and the output effect. Our only assumptions at this point are that the plaintiff takes its input prices as given, including the price of the input purchased from the cartel, and chooses its input mix to minimize its total costs. We do not yet make specific assumptions as to the nature of competition in the plaintiff’s industry.

Consider a plaintiff firm selling  $q$  units of total output at a price  $p$ . The plaintiff chooses its inputs to minimize its total costs, subject to a standard production function technology. One of its inputs is the cartelized input, of which it purchases  $x$  units at an input price  $w$ . Write the plaintiff’s cost

<sup>5</sup> Joined cases C-192/95 to C-218/95 *Société Comateb*, 1997 ECR I 165, CJ (<http://europa.eu.int/eur-lex/lex/LexUriServ/LexUriServ.do?uri=CELEX:61995J0192:EN:HTML>).

<sup>6</sup> C-453/99 *Courage v. Crehan* 2001 ECR I-6297 CJ.

<sup>7</sup> The legal part of the Ashurst study was written by Waelbroeck, Slater and Even-Shoshan [2004].

<sup>8</sup> Very recently, the European Commission [2008] published a White Paper, in which it recommends that all affected parties have legal standing to claim damages and where it allows for the possibility of a passing-on defense.

function  $C(w, q)$  as a function of  $w$  and  $q$ , and omit the other input prices as arguments. The plaintiff's profits  $\pi$  are simply total revenues minus total costs:

$$\pi = pq - C(w, q).$$

We assume that the formation of the cartel leads to an increase in the input price  $w$ . The corresponding price overcharge is defined as the cartel input price  $w_1$  minus the but-for input price  $w_0$  (i.e., the input price as it would have been without the cartel). We will follow a differential approach and consider the effects on the plaintiff's profits of a 'small cartel,' i.e., a small price overcharge  $dw$ . This is similar to Farrell and Shapiro's [1990] approach of looking at the effects of an 'infinitesimal merger.' It has the advantage of highlighting in a simple way the key channels through which the cartel affects the plaintiff's profits. It ignores however second-order effects which may become potentially important for large price overcharges  $w_1 - w_0 = \int_{w_0}^{w_1} dw$ .<sup>9</sup> The change in the plaintiff's profits due to a small cartel or small price overcharge  $dw$  is:

$$d\pi = -\frac{\partial C(w, q)}{\partial w} dw + qdp + \left(p - \frac{\partial C(w, q)}{\partial q}\right) dq.$$

According to Shepard's Lemma, the plaintiff's demand for the cartelized input is  $x = \frac{\partial C(w, q)}{\partial w}$ , so that

$$(1) \quad d\pi = -xdw + qdp + \left(p - \frac{\partial C(w, q)}{\partial q}\right) dq.$$

Equation (1) shows that the change in the plaintiff's profits due to the cartel can be decomposed into three components.

*Price overcharge or cost effect.* This effect ( $-xdw$ ) is the input price increase  $dw$ , multiplied by the total inputs  $x$  purchased from the cartel. This effect on profits is obviously negative.

*Pass-on effect.* This effect ( $qdp$ ) is the increase in revenue that follows if the plaintiff passes part of the input price increase on to its customers in the form of a higher output price  $dp$ . The pass-on is typically positive ( $dp > 0$ ), thus counteracting at least part the direct damages from the price overcharge  $dw$ .

<sup>9</sup> One such effect arises from distortionary input substitution away from the cartelized input. The size of the price overcharge and the implied second-order effects is an empirical question, and typically varies widely; see e.g., Connor [2004] and Levenstein and Suslow [2006]. Extending our framework to allow for large price overcharges would entail integrating over the small overcharges  $dc$ . This does not give general closed form solutions, but simulation analysis based on specific functional form assumptions (as in merger analysis) would provide a solution.

*Output effect.* This effect  $\left(p - \frac{\partial C(w,q)}{\partial q}\right) dq$  refers to the lost profits associated with any lost sales  $dq$  following the higher output price set by the plaintiff. This effect is typically negative ( $dq < 0$ ), especially if the plaintiff earns a high profit margin  $p - \frac{\partial C(w,q)}{\partial q}$ , as in imperfectly competitive markets. The output effect can only be ignored if the plaintiff is active in a perfectly competitive market, since then  $p = \frac{\partial C(w,q)}{\partial q}$ .

The price overcharge or cost effect forms the basis for the plaintiff's cartel damages claims in both the U.S. and Europe. The defendant may subsequently attempt to resort to the pass-on effect to obtain a discount from the price overcharge, at least if this has a legal basis in the jurisdiction. However, our framework shows that the pass-on effect also implies an output effect. Hence, if a passing-on defense is allowed the output effect should also be incorporated.

While our framework stresses the role of three key effects from the cartel in general terms, it does not say anything about their relative magnitudes. In the next sections, we shall introduce additional structure on the competitive conditions in the plaintiff's downstream market to quantify the relative importance of the three effects. For example, if the plaintiff behaves as a monopolist, the pass-on and output effects cancel out from the monopolist's first-order condition. More generally, we identify conditions under which the pass-on effect dominates the output effect. This motivates an adjusted passing-on defense in the form of easy-to-interpret discounts to the cost effect. We begin with the simpler case of a common cost increase, where all firms in the plaintiff's downstream market are symmetrically affected by the price overcharge  $dw$ , and subsequently move to the more complicated setting in which some of the plaintiff's rivals are not affected.

*Constant Returns to Scale.* To simplify the exposition, the rest of the paper assumes that the plaintiff has a constant returns to scale cost function,  $C(w, q) = c(w)q = cq$ .<sup>10</sup> This implies that marginal cost is independent of output,  $\frac{\partial C(w,q)}{\partial q} = c(w) = c$ , and that input demand is proportional to total output,  $x = \frac{\partial C(w,q)}{\partial w} = c'(w)q$ . Furthermore,  $dc = c'(w)dw = \frac{x}{q}dw$ . The change in the plaintiff's profits, given by (1), then simplifies to:

$$(2) \quad d\pi = -qdc + qdp + (p - c)dq.$$

Equation (2) expresses the cartel's price overcharge in terms of the overall marginal cost increase,  $dc$ , instead of the input price increase,  $dw$ . We will follow this practice in the rest of the paper. To reinterpret our results in terms of the input price increase  $dw$ , simply substitute  $dc = \frac{x}{q}dw$ .

<sup>10</sup> The assumption of constant marginal cost is not without consequences. If marginal cost were increasing in output, the extent of pass-on could be expected to be smaller, which would also result in a lower output effect. The reverse is true if marginal cost is decreasing in output.

## IV. COMMON COST INCREASE

We begin with the situation in which the cartel affects all firms in the plaintiff's industry. More specifically, assume that all firms have the same (constant) marginal cost  $c$  prior to the cartel and are subject to a common marginal cost increase  $dc$  due to the cartel. Let the plaintiff's demand when all firms set the same price  $p$  be  $q = H(p)$ . This is the traditional Chamberlinian  $DD$  curve. Assume this is a constant fraction  $\alpha$  of total industry demand when all firms set the same price, i.e.,  $H(p) = \alpha Q(p)$ .<sup>11</sup> The industry-level price elasticity of demand is then given by  $\varepsilon = -\frac{\partial Q(p)}{\partial p}/\frac{p}{Q(p)} = -\frac{\partial H(p)}{\partial p}/\frac{p}{H(p)}$ . Assume that the cost, demand and competitive conditions generate a symmetric equilibrium, i.e., an equilibrium in which all firms sell their output at the same price  $p$ . Denote the equilibrium price as a function of the common marginal cost by  $p = p^*(c)$ . Assume this function is increasing in  $c$ , and define the industry-level pass-on rate by  $\tau = \frac{\partial p^*(c)}{\partial c} > 0$ . While this set-up imposes much symmetry, it allows for various sources of market power in the plaintiff's market: product differentiation, the number of competitors, and the competitive conduct (e.g., Bertrand versus Cournot). This will be illustrated with specific models below.

The plaintiff's equilibrium profits as a function of the common marginal cost are:

$$\pi(c) = (p^*(c) - c)H(p^*(c)).$$

The change in its profits due to the cartel, given in general by (2), is therefore:

$$(3) \quad d\pi = \left( -q + q \frac{\partial p^*(c)}{\partial c} + (p - c) \frac{\partial H(p)}{\partial p} \frac{\partial p^*(c)}{\partial c} \right) dc.$$

This confirms that the cartel has three effects: a price overcharge or cost effect (first term), and the pass-on and output effects (second and third terms). But the additional structure on the plaintiff's downstream market now enables us to quantify the relative importance of these three effects in terms of familiar economic concepts. To see this, define

$$(4) \quad \lambda = \frac{p - c}{p} \varepsilon$$

as the competition intensity parameter for the plaintiff's industry, as in Corts [1999]. This is a number between zero and one, measuring the plaintiff's actual markup  $\frac{p-c}{p}$  relative to the maximum markup it could achieve as a monopolist or as a member of a downstream cartel ( $\frac{1}{\varepsilon}$ ). Substituting the

<sup>11</sup> The assumption of a constant fraction generalizes the usual full symmetry assumption that firms obtain the same fraction of industry demand.

definitions of  $\varepsilon$ ,  $\tau$  and  $\lambda$  in (3) and rearranging, we can write the change in the plaintiff's profit due to the cartel as:

$$(5) \quad d\pi = -(1 - (1 - \lambda)\tau)qdc.$$

Equation (5) says that the price overcharge or cost effect of the cartel ( $-qdc$ ) forms a starting basis for computing cartel damages, but that a discount equal to  $(1 - \lambda)\tau$  should be applied. Since  $\tau > 0$  and  $\lambda$  is between zero and one, this discount is positive or zero, but less than the pass-on rate. We therefore have:

*Proposition 1.* Consider a symmetric industry with a common cost increase due to the cartel. The appropriate discount to the price overcharge suffered by the plaintiff is weakly positive, and is given by:

$$(6) \quad \text{discount} = (1 - \lambda)\tau \geq 0.$$

An adjusted passing-on defense is therefore justified, unless the plaintiff's downstream industry is itself fully cartelized ( $\lambda = 1$ ).<sup>12</sup>

The downward adjustment of the pass-on rate in computing the discount stems from the fact that pass-on may lead to a further output effect. In a perfectly competitive industry ( $\lambda = 0$ ), the output effect is absent since lost sales do not matter at the margin (since markups are zero). The discount to the overcharge is then simply the unadjusted pass-on rate. But as the plaintiff's industry becomes less competitive ( $\lambda > 0$ ), the lost sales do matter, and the pass-on rate should be adjusted downwards. In the extreme case in which the plaintiff's industry is fully cartelized ( $\lambda = 1$ ), the output effect actually fully offsets the pass-on effect and the discount to the overcharge becomes zero. The passing-on defense would thus not be justified, as has also been observed for this extreme case by Hellwig [2006] and Kosicki and Cahill [2006].

We now apply two standard oligopoly models to the plaintiff's industry to show how these results can be made operational: Bertrand competition and quantity competition with conjectural variations (with Cournot competition as a special case). Applications to other symmetric models may also be possible, e.g., bilateral oligopoly with negotiated prices.

#### IV(i). Bertrand Competition

With Bertrand competition in the plaintiff's industry, each firm chooses its price to maximize its own profits, taking as given the prices set by the other

<sup>12</sup> While the discount to the overcharge is generally positive (unless  $\lambda = 1$ ), it is not necessarily less than one. The discount may be greater than one if the pass-on rate  $\tau > 1$  and if  $\lambda$  is sufficiently small. In this case, the plaintiff would actually gain from the common cost increase due to the cartel.

firms. Market power then stems from the degree of product differentiation and the number of competing firms. Let the plaintiff's own demand when it sets a price  $p$  and its rivals all set the same price  $r$  be  $D(p, r)$ . If  $p = r$ , we obtain the Chamberlinian  $DD$  curve,  $D(p, p) = H(p)$ . The first-order condition defining a symmetric Bertrand-Nash equilibrium is:

$$(7) \quad (p - c) \frac{\partial D(p, p)}{\partial p} + D(p, p) = 0.$$

Define the plaintiff's firm-level own-price elasticity of demand, evaluated at equal prices  $p = r$ , as  $\eta = -\frac{\partial D(p, p)}{\partial p} \frac{p}{D(p, p)}$ . Furthermore, define  $\delta = -\frac{\partial D(p, p)}{\partial r} / \frac{\partial D(p, p)}{\partial p}$ , i.e., the ratio of the cross-price effect of a price increase by the rivals over the own-price effect. If there are no income effects, the firms' cross-price effects are symmetric, so that  $\delta$  can be interpreted as the plaintiff's aggregate diversion ratio, i.e., the fraction of the sales lost by the plaintiff after a price increase that flows back to its rivals in the industry.<sup>13</sup> Differentiating  $D(p, r)$  and  $H(p)$  and evaluating at equal prices  $p = r$ , one can verify that the industry-level price elasticity  $\varepsilon$  is related to the product-level own-price elasticity  $\eta$  through  $\varepsilon = \eta(1 - \delta)$ . The Bertrand-Nash equilibrium condition (7) can then be written in the following two ways:

$$\begin{aligned} \frac{p - c}{p} &= \frac{1}{\eta} \\ &= \frac{1 - \delta}{\varepsilon}. \end{aligned}$$

Substituting this in (4), we obtain  $\lambda = \frac{\varepsilon}{\eta} = 1 - \delta$ . We can then apply the discount formula (6) to obtain the following corollary to Proposition 1:

*Corollary 1.* In a symmetric Bertrand industry with a common cost increase the appropriate discount to the price overcharge is:

$$(8) \quad \begin{aligned} \text{discount} &= \left(1 - \frac{\varepsilon}{\eta}\right)\tau \\ &= \delta\tau. \end{aligned}$$

The first expression shows that the discount can be obtained by adjusting the pass-on rate using information on the firm-level and market-level price

<sup>13</sup> To see this formally, we need some additional demand notation. Let  $D_i(\mathbf{p})$  be firm  $i$ 's own demand as a function of the vector of prices set by all firms  $\mathbf{p}$ . The aggregate diversion ratio of firm  $i$  is defined as  $-\sum_{j \neq i} \frac{\partial D_i(\mathbf{p})}{\partial p_j} / \frac{\partial D_i(\mathbf{p})}{\partial p_i}$ . With symmetric price effects  $\frac{\partial D_i(\mathbf{p})}{\partial p_i} = \frac{\partial D_i(\mathbf{p})}{\partial p_j}$ , we can write this as  $-\sum_{j \neq i} \frac{\partial D_i(\mathbf{p})}{\partial p_j} / \frac{\partial D_i(\mathbf{p})}{\partial p_i}$  which is indeed equal to  $\delta = -\frac{\partial D(p, p)}{\partial r} / \frac{\partial D(p, p)}{\partial p}$ .

elasticities of demand. The using information on the plaintiff's aggregate diversion ratio. For example, if  $\tau = 60\%$  and  $\delta = 50\%$ , the defendant can claim a 30% discount from the price overcharge.

*Example: logit demand.* To illustrate, consider the logit model, which has been popular in many areas of antitrust analysis; see for example Werden and Froeb [1994]. There are  $N$  symmetrically differentiated products and one outside good, the no-purchase alternative. There are  $L$  potential consumers who either buy one of the differentiated products, or the 'outside good' at an exogenous price  $p_0$ . The plaintiff's own demand as a function of its own price  $p$  and the identical rivals' prices  $r$  is

$$D(p, r) = \frac{\exp(-p)}{\exp(p_0) + \exp(-p) + (N - 1)\exp(-r)} L,$$

and its portion of total industry demand as a function of a common industry price (the Chamberlinian  $DD$  curve) is:

$$H(p) = \frac{\exp(-p)}{\exp(p_0) + N\exp(-r)} L = s(p)L,$$

where  $s(p)$  is the plaintiff's market share in the total number of potential consumers. One can easily verify that  $\eta = s(p)(1 - s(p))p$ , and  $\varepsilon = s(p)(1 - Ns(p))p$ . This implies that  $\lambda = \frac{1 - Ns(p)}{1 - s(p)}$ , so that the discount to the overcharge is

$$\text{discount} = \frac{(N - 1)s(p)}{1 - s(p)} \tau.$$

This discount can be computed using information on the pass-on rate, the number of firms and the plaintiff's market share in the total number of potential consumers.

#### IV(ii) *Quantity Competition with Conjectural Variations*

Now suppose that the firms in the plaintiff's industry compete according to a homogeneous goods quantity competition model with conjectural variations. Let  $p = P(Q)$  denote the inverse industry demand function, where  $Q = \sum_{i=1}^N q_i$  is total industry output, i.e., the sum of the quantities produced by the  $N$  firms. In the standard Cournot model, each firm chooses its quantity to maximize its profits, taking as given the quantities of the other firms. In the conjectural variations extension, each firm 'conjectures' that a change in its own quantity induces the other firms to respond. Let the conjectural variations parameter  $\theta$  be each firm's conjectured change in total output  $Q$  when a firm changes its own quantity by one unit. The first-order condition defining a symmetric conjectural

variations equilibrium is

$$(9) \quad P(Q) - c + P'(Q)\theta \frac{Q}{N} = 0.$$

This condition nests several well-known special cases. If  $\theta = 1$ , each firm conjectures that total output increases by the same amount as its own quantity (i.e., it takes the quantities of the other firms as given), so that the standard Cournot condition obtains. If  $\theta = N$ , each firm conjectures that each rival will fully match a quantity increase, so that the condition of a perfect cartel obtains. If  $\theta = 0$ , each firm conjectures that the rivals contract their quantities in response to a change in its own quantity, in such a way that total output remains constant. In this case, the condition of perfect competition obtains. Outside such special cases, the conjectural variations model has little game-theoretic appeal, since it aims to capture dynamic responses within a static model. It has, however, often been used in empirical work to estimate the conduct or average collusiveness of firms without having to specify a full dynamic model. The critical debate on the interpretation and estimation of  $\theta$  is ongoing, as illustrated by the critical discussions in Bresnahan [1989], Corts [1999] and Reiss and Wolak [2005]. We nevertheless include it here to show how it fits nicely into our framework for computing discounts to the price overcharge.

Using the industry-level price elasticity  $\varepsilon = -\frac{1}{P'(Q)} \frac{P(Q)}{Q}$ , the conjectural variations equilibrium condition (9) can be rewritten as

$$\frac{p - c}{p} = \frac{\theta}{N} \frac{1}{\varepsilon}.$$

Based on (4), we can compute  $\lambda = \frac{\theta}{N}$  and apply this to the discount formula to obtain a second corollary to Proposition 1:

*Corollary 2.* In a symmetric Cournot conjectural variation industry with a common cost increase the appropriate discount to the price overcharge is:

$$(10) \quad \text{discount} = \left(1 - \frac{\theta}{N}\right)\tau.$$

For example, in the standard Cournot model  $\theta = 1$ , so that only information on the number of firms is required to adjust the pass-on rate and obtain the discount.

## V. FIRM-SPECIFIC COST INCREASE

In a variety of settings it is not appropriate to assume that the cartel leads to a cost increase common to all firms in the plaintiff's industry. First, one or more of the cartel members may be vertically integrated and therefore also be active as a downstream competitor in the plaintiff's industry. Such a firm

could then decide to favour its own downstream unit and only charge a high input price to the downstream competitors.<sup>14</sup> To the extent that such raising rivals' costs behavior would occur, the plaintiff experiences a competitive disadvantage relative to some of its rivals, so that it is no longer appropriate to apply the above analysis of a common cost increase.

Second, the cartel members may not be able to control perfectly the supply of their input. Some of the plaintiff's downstream competitors may be able to purchase their inputs from suppliers outside the cartel, or from foreign suppliers if the cartel is national, etc. The plaintiff then also suffers a competitive disadvantage relative to its rivals, so that the analysis of a common cost increase is again no longer valid.

This motivates an analysis of firm-specific cost increases due to the cartel. The general framework of section 3 still applies, i.e., there is a price overcharge or cost effect, a pass-on effect and an output effect. However, the relative magnitudes of these effects no longer follow the simple relations obtained for common cost increases in section 4. In particular, the output effect becomes potentially more important since the plaintiff loses to other firms in its industry as it passes on part of the cost increase. As we will show, it is even possible that the output effect dominates the pass-on effect.

To obtain concrete insights on firm-specific cost increases, we first consider a Bertrand model with differentiated products and subsequently a Cournot model with homogeneous products.

### V(i). Bertrand Competition

There are  $N$  price-setting firms,  $i = 1 \dots N$ , selling differentiated products. Let  $I$  be the group of affected firms, i.e., the firms affected by the cost increase due to the cartel. One of these affected firms is the plaintiff, denoted by firm 1. Each firm  $i$  sells a single product and sets a price  $p_i$ , operating at a constant marginal cost  $c_i$ . Firm  $i$ 's profits in the but-for world (without the cartel) are

$$\pi_i = (p_i - c_i)D_i(\mathbf{p}),$$

where  $q_i = D_i(\mathbf{p})$  is its demand, as a function of the  $N \times 1$  price vector  $\mathbf{p} = (p_1 \dots p_N)$ . Demand is downward sloping  $\frac{\partial D_i(\mathbf{p})}{\partial p_i} < 0$ , products are gross substitutes  $\frac{\partial D_i(\mathbf{p})}{\partial p_k} > 0$  for  $k \neq i$ , there are no income effects, so that the cross-price effects are symmetric  $\frac{\partial D_i(\mathbf{p})}{\partial p_k} = \frac{\partial D_k(\mathbf{p})}{\partial p_i}$ , and the Jacobian is negative-definite. Let the diversion ratio between the plaintiff firm 1 and any other firm  $k \neq 1$  be  $\delta_1^k = -\frac{\partial D_k(\mathbf{p})}{\partial p_1}/\frac{\partial D_1(\mathbf{p})}{\partial p_1}$ . This is the fraction of firm 1's lost sales that

<sup>14</sup> It is not obvious whether a vertically integrated firm would actually have an incentive to engage in such foreclosure; see e.g., Rey and Tirole [2006]. So in real antitrust cases, this should be separately investigated on a case by case basis.

diverts to firm  $k$  after a price increase by firm 1. Furthermore, let firm 1's aggregate diversion ratio be  $\delta_1 = \sum_{k \neq 1} \delta_1^k < 1$ , i.e., the fraction of firm 1's lost sales that flows to other firms within the industry.<sup>15</sup>

The system of first-order conditions defining a Bertrand-Nash equilibrium is

$$(11) \quad (p_i - c_i) \frac{\partial D_i(\mathbf{p})}{\partial p_i} + D_i(\mathbf{p}) = 0, \quad i = 1 \dots N$$

and assume that the second-order conditions are satisfied. Denote  $\mathbf{p} = p^*(\mathbf{c})$  as the price vector that solves (11) as a function of the marginal cost vector  $\mathbf{c} = (c_1 \dots c_N)$ . Define  $\tau_i^k = \frac{\partial p_k^*(\mathbf{c})}{\partial c_i}$  as the firm-specific pass-on rate of firm  $k$  with respect to a cost increase of firm  $i$ , and assume  $\tau_i^k > 0$  for all  $i, k$ . Furthermore, define  $\tau_I^k = \sum_{i \in I} \tau_i^k$  as the group-level pass-on rate of firm  $k$ , i.e., firm  $k$ 's pass-on rate with respect to a cost increase of all firms affected by the cartel  $i \in I$ .

We are interested in the effect of the cartel on the plaintiff firm 1's profits. Firm 1's equilibrium profits as a function of the marginal cost vector  $\mathbf{c}$  in the but-for world are

$$\pi_1(\mathbf{c}) = (p_1^*(\mathbf{c}) - c_1) D_1(p^*(\mathbf{c})).$$

Assume that the cartel raises all affected firms' marginal costs by the same amount as the plaintiff and does not affect the others' marginal costs, i.e.,  $dc_i = dc_1$  for  $i \in I$  and  $dc_i = 0$  for  $i \notin I$ . The change in plaintiff firm 1's profits in response to the cartel is then equal to

$$(12) \quad \begin{aligned} d\pi_1 &= \sum_{i=1}^N \frac{\partial \pi_1(\mathbf{c})}{\partial c_i} dc_i \\ &= \sum_{i \in I} \frac{\partial \pi_1(\mathbf{c})}{\partial c_i} dc_1 \\ &= \left( -q_1 + q_1 \sum_{i \in I} \frac{\partial p_1^*}{\partial c_i} + (p_1 - c_1) \sum_{i \in I} \left( \frac{\partial D_1}{\partial p_1} \frac{\partial p_1^*}{\partial c_i} + \dots + \frac{\partial D_1}{\partial p_N} \frac{\partial p_N^*}{\partial c_i} \right) \right) dc_1. \end{aligned}$$

This reconfirms that the cartel has three effects. The first term is the price overcharge or cost effect and is proportional to minus firm 1's sales,  $-q_1$ . The second term is the pass-on effect. It is positive and proportional to firm 1's sales, multiplied by the extent to which firm 1 passes on the marginal cost increases of the affected group. The third term is the output effect. It is proportional to firm 1's profit margin, multiplied by the extent to which firm

<sup>15</sup>This is the same as the aggregate diversion ratio  $\delta$  defined earlier in the symmetric framework.

1 loses sales through the equilibrium price responses of all firms (both the affected and the unaffected firms).

We now show that the positive pass-on effect dominates the output effect, so that an adjusted passing-on defense is valid under the general conditions of the Bertrand model. To see this, substitute firm 1's first-order condition (11) and the symmetric cross-effects  $\frac{\partial D_1}{\partial p_k} = \frac{\partial D_k}{\partial p_1}$  in the profit change (12). Then apply the definitions of the diversion ratios  $\delta_1^k$  and the pass-on rates  $\tau_I^k$  to obtain:

$$(13) \quad d\pi_1 = -(1 - \delta_1^2 \tau_I^2 - \cdots - \delta_1^N \tau_I^N) q_1 dc_1.$$

Equation (13) says that the price overcharge ( $-qdc$ ) should be discounted by the amount  $\delta_1^2 \tau_I^2 + \cdots + \delta_1^N \tau_I^N$ . Since  $\delta_1^k > 0$  for  $k \neq 1$  and  $\tau_I^k > 0$ , this discount is generally positive. We therefore have:

*Proposition 2.* Consider a Bertrand industry where cost increases for a group of firms  $I$  only, including the plaintiff firm 1. The appropriate discount to the price overcharge suffered by plaintiff firm 1 is positive, and is given by

$$(14) \quad \text{discount} = \delta_1^2 \tau_I^2 + \cdots + \delta_1^N \tau_I^N > 0.$$

An adjusted passing-on defense is therefore justified.<sup>16</sup>

The discount to the overcharge (14) reflects the combined pass-on and output effects. Intuitively, it is equal to a weighted-average of the group-level pass-on rates over all firms except the plaintiff firm 1, where the weights are the diversion ratios with respect to firm 1. The adjusted passing-on defense should however be carefully interpreted. It is *not* the fact that plaintiff firm 1 is able to pass on the affected firms' cost increase that justifies resorting to the passing-on defense. This term is actually only a second-order effect because it is fully compensated by an output effect.<sup>17</sup> In contrast, it is that fact that all *other* firms than the plaintiff also raise their prices in response to the cost increases that justifies the passing-on defense. These other firms' price responses are first-order effects and raise the plaintiff's profits through increased output.

The question of practical interest is of course how to measure the discount to the overcharge (14). A first approach is to obtain an econometric estimate of the group-level pass-on rates for all firms that are active in the downstream market. The discount can then be computed from (14) using quantitative or qualitative information on the diversion ratios as weights. This approach may require a substantial amount of information in practice.

<sup>16</sup> The discount may be greater than one if some of the pass-on rates  $\tau_I^k > 1$  and the corresponding diversion ratios  $\delta_1^k$  are sufficiently close to 1.

<sup>17</sup> Formally, after substituting firm 1's first-order condition (11) the pass-on term  $q_1 \sum_{i \in I} \frac{\partial p_i^*}{\partial c_i}$  cancels out with part of the output term in (12).

As an alternative, one may make additional assumptions to obtain a more explicit expression of the discount formula. We discuss two examples next. *Identical firms without the cartel.* Suppose that all firms in the plaintiff's industry are identical in the but-for world, and are correspondingly in a symmetric Bertrand-Nash equilibrium. The cartel subsequently raises the marginal costs of the firms in the affected group  $I$ . With identical firms in the but-for world, the group-level pass-on rates are all equal, i.e.,  $\tau_I^k = \tau_I$  for all  $k$ . Using the aggregate diversion ratio  $\delta_1 = \sum_{k \neq 1} \delta_1^k$ , the discount formula (14) simplifies to

$$(15) \quad \text{discount} = \delta_1 \tau_I^I.$$

This generalizes our earlier discount formula (8) for the symmetric Bertrand industry with a common cost increase. The crucial difference is that the group-level pass-on rate  $\tau^I$  now enters instead of the industry-level pass-on rate  $\tau$ . Since the group-level pass-on rate is typically lower than the industry-level pass-on rate, the discount to the overcharge is clearly also lower.

*Symmetric substitution patterns and logit demand.* Now allow firms to be different, but assume that the demand side is characterized by symmetric substitution patterns. This means that a loss in the market share of plaintiff firm 1 (or of any other firm) is associated with an increase in the market shares of the rivals in proportion to their market shares. This is a property of random utility discrete choice models of demand, when the independence of irrelevant alternatives (IIA) assumption is satisfied. The diversion ratio between firm 1 and firm  $k$  is then equal to  $\delta_1^k = \frac{s_k}{1-s_1}$ , where  $s_k$  is the market share of firm  $k$  in the total number of potential consumers  $L$ . The discount (14) can then be written as

$$(16) \quad \text{discount} = \frac{1}{1 - s_1} (s_2 \tau_I^2 + \cdots + s_N \tau_I^N).$$

Hence, the discount equals the weighted average of the rivals' pass-on rates where the market shares are the weights. Equivalently, one can interpret this discount as the effect of the affected firms' cost increase on the price index for the whole industry except firm 1 (using fixed market shares as weights).

To avoid econometric estimation of the pass-on rates, one may further specify the demand model and compute the pass-on rates as a function of observables or a limited set of parameters. To illustrate this, consider the earlier discussed logit model of demand, but now allowing firms to differ in quality or costs. The logit model satisfies the IIA assumption and correspondingly entails symmetric substitution patterns. In the Appendix we derive explicit formula for the pass-on rates  $\tau_i^k$  as a function of observable market shares  $s_i$ , i.e., shares of each firm  $i$  in the total potential sales. Substituting these in (16) and rearranging, one can write the formula for the

discount as:

$$(17) \quad \text{discount} = \frac{\sum_{i \in I} T_i - s_1(1 - s_1)}{(1 - s_1)^2 + s_1},$$

where

$$T_i = \frac{s_i(1 - s_i)^2}{(1 - s_i)^2 + s_i} \left/ \left( s_0 + \sum_{k=1}^N \frac{s_k(1 - s_k)^2}{(1 - s_k)^2 + s_k} \right) \right.,$$

and  $s_0$  is the market share of the outside good.<sup>18</sup> This shows that the discount to the price overcharge can be computed using only information on the market shares of all firms, including the outside good, and on the identity of the affected firms. While the market share of the outside good is typically not known, it can be calibrated using information on the market-level price elasticity of demand. For example, if the market-level elasticity is approximately zero, then  $s_0 = 0$ .

One can immediately verify that the logit discount is indeed always positive. In addition, the discount is always less than 1. Furthermore, it approaches 1 if there is a common cost increase and perfectly inelastic industry-level demand (i.e., the number of affected firms is equal to  $N$  and the market share of the outside good  $s_0 \rightarrow 0$ ).

To gain additional intuition on the logit discount formula, Table I computes the discounts for alternative values of the number of firms in the plaintiff's market, the number of unaffected firms, and the plaintiff's market share. The table assumes that the outside good has a market share of 10%, that the plaintiff firm 1 has a market share of either 10% or 50%, and that the other firms share the rest of the market equally. The table confirms that the discount is less than 100% but always positive, even if all firms except the plaintiff are unaffected (bold numbers on diagonal). We can make three additional observations. First, a comparison across the rows shows that the discount decreases with the number of unaffected firms. Second, a comparison across the columns shows that the discount increases with the degree competition in the plaintiff's market (holding the number of unaffected firms constant). Third, a comparison between the left and right panel shows that the discount is often larger if plaintiff has a small market share. To illustrate its practical relevance, we apply the logit discount formula to the European vitamin cartel in section 6.

<sup>18</sup> The market share of the outside good enters the discount formula differently from the other shares, because the price of this product remains constant after the cost change unlike the prices of the other products.

TABLE I  
DISCOUNT TO THE COST EFFECT OF THE CARTEL: BERTRAND COMPETITION

Unaffected firms	Plaintiff's market share: 10%			Plaintiff's market share: 50%		
	Number of firms in the plaintiff's market					
	2	6	10	2	6	10
logit demand						
0	52%	87%	88%	71%	79%	79%
1	<b>33%</b>	70%	78%	<b>15%</b>	63%	71%
5	—	<b>2%</b>	40%	—	<b>2%</b>	36%
9	—	—	<b>1%</b>	—	—	<b>1%</b>

Notes: The numbers are based on the discount formula (17). The market shares are as follows: outside good = 10%; plaintiff = 10% or 50%; other firms: identical share of remaining part. The numbers in bold refer to common cost increases (all firms are insiders).

### V(ii). Cournot Competition

There are  $N > 1$  quantity-setting firms, selling a homogeneous product. Let  $I$  again be the group of affected firms, and let  $N_I$  be the number of affected firms. One of the affected firms is the plaintiff, again denoted by firm 1. Each firm  $i = 1 \dots N$  produces a quantity  $q_i$  at a constant marginal cost  $c_i > 0$ . Total industry output is  $Q = \sum_{k=1}^N q_k$  and the average of all firms' marginal costs is  $\bar{c} = \sum_{k=1}^N c_k/N$ . Let the inverse industry demand function be  $p = P(Q)$ , with  $P'(Q) < 0$ . The price elasticity of industry demand is  $\varepsilon = -\frac{1}{P'(Q)} \frac{P(Q)}{Q}$ . A measure of the curvature of industry demand is the elasticity of the slope of the inverse demand curve, i.e.,  $\rho = -P''(Q) \frac{Q}{P'(Q)}$ ; see e.g., Vives [1999]. If  $\rho < 0$ , demand is concave; if  $\rho = 0$ , demand is linear; and if  $\rho > 0$ , demand is convex. A well-known example of convex demand is the constant elasticity demand case, for which  $\rho = \frac{1+\varepsilon}{\varepsilon}$ .<sup>19</sup> Each firm  $i$  chooses to produce its quantity  $q_i$  to maximize profits

$$\pi_i = (P(Q) - c_i)q_i,$$

taking as given the quantities chosen by the rival firms. The system of necessary first-order conditions defining a Cournot-Nash equilibrium is

$$(18) \quad P(Q) - c_i + P'(Q)q_i = 0, \quad i = 1 \dots N.$$

Assume that  $P'(Q) + P''(Q)q_i \leq 0$  for all  $i$ . Given constant marginal costs  $c_i$ , this assumption ensures the existence of a unique Cournot-Nash

<sup>19</sup>An often-used related measure for the demand curvature is the elasticity of the elasticity. This is defined by  $E = \varepsilon'(Q) \frac{1}{P'(Q)\varepsilon(Q)}$ . It can be verified that  $\rho = \frac{\varepsilon+1-E}{\varepsilon}$ . Our measure gives simpler expressions below.

equilibrium.<sup>20</sup> The assumption is equivalent to  $1 - \rho s_i \geq 0$  for all  $i$ , where  $s_i = q_i/Q$  is firm  $i$ 's market share. It also implies that  $N - \rho \geq 0$ .

To perform comparative statics of the cost increase due to the cartel, first define the equilibrium quantities and price as a function of the marginal costs. Adding up the first-order conditions gives

$$(19) \quad (P(Q) - \bar{c})N + P'(Q)Q = 0.$$

Under the above assumptions, the left-hand-side of (19) is decreasing in  $Q$  and  $\bar{c}$  and implicitly defines the equilibrium industry output function,  $Q = Q^*(\bar{c})$ , decreasing in  $\bar{c}$ . Furthermore, using the inverse industry demand function, we can also define the equilibrium price function  $p = p^*(\bar{c}) = P(Q^*(\bar{c}))$ , increasing in  $\bar{c}$ . Implicitly differentiating (19), using the definition of  $\rho$ , and rearranging, we obtain

$$(20) \quad \tau = \frac{\partial p^*(\bar{c})}{\partial \bar{c}} = \frac{N}{N + 1 - \rho}.$$

This can be interpreted as the industry-level pass-on rate since  $\tau = \frac{\partial p^*(\bar{c})}{\partial \bar{c}} = \sum_{i=1}^N \frac{\partial p^*(\bar{c})}{\partial \bar{c}} \frac{\partial \bar{c}}{\partial c_i}$ . Note that  $\tau > 0$  since  $N + 1 - \rho > N - \rho \geq 0$ . Note also that pass-on is incomplete, i.e.,  $\tau < 1$ , if and only if  $\rho < 1$ . Finally, substituting  $Q = Q^*(\bar{c})$  in the first-order condition (18) gives

$$(21) \quad P(Q^*(\bar{c})) - c_i + P'(Q^*(\bar{c}))q_i = 0.$$

Equation (21) implicitly defines firm  $i$ 's equilibrium output function  $q_i = q_i^*(\bar{c}, c_i)$ . Under the above assumptions (21) is decreasing in  $q_i$ , increasing in  $\bar{c}$  and decreasing in  $c_i$ , so that  $q_i^*(\bar{c}, c_i)$  is increasing in  $\bar{c}$  and decreasing in  $c_i$ .

As before, we are interested in the effect of the cartel on the plaintiff firm 1's profits. Firm 1's equilibrium profits in the but-for world can be written as a function of the average of all firms' marginal costs  $\bar{c}$  and its own marginal cost  $c_1$ :

$$\pi_1(\bar{c}, c_1) = (p^*(\bar{c}) - c_1)q_1^*(\bar{c}, c_1).$$

Assume again that the cartel affects the marginal costs of all firms in the affected group by the same amount as the plaintiff and does not affect the other firms,  $dc_i = dc_1$  for  $i \in I$  and  $dc_i = 0$  for  $i \notin I$ . The change in plaintiff

<sup>20</sup>Vives [1999] provides a more detailed discussion of these and weaker conditions for the existence, uniqueness and stability of Cournot equilibrium.

firm 1's profits in response to the cartel then equals

$$\begin{aligned}
 d\pi_1 &= \sum_{i=1}^N \frac{\partial \pi_1(\bar{c}, c_i)}{\partial c_i} dc_i \\
 (22) \quad &= \sum_{i \in I} \frac{\partial \pi_1(\bar{c}, c_i)}{\partial c_i} dc_i \\
 &= \left( -q_1 + q_1 \sum_{i \in I} \left( \frac{\partial p^*}{\partial \bar{c}} \frac{1}{N} \right) + (p - c_1) \sum_{i \in I} \left( \frac{\partial q_1^*}{\partial \bar{c}} \frac{1}{N} + \frac{\partial q_1^*}{\partial c_i} \right) \right) dc_1.
 \end{aligned}$$

The first term is the price overcharge or the cost effect of the cartel and is clearly negative. The second term is the group-level pass-on effect and it is positive since  $\tau > 0$ . Using (20), it can be written as  $q_1 \frac{N_I}{N} \tau$ , i.e., it is proportional to the industry-wide pass-on rate times the fraction of affected firms  $\frac{N_I}{N}$ . The third term is the output effect and is typically negative.

We now show that in contrast to the Bertrand model, the negative output effect may be so strong that it actually dominates the positive pass-on effect. This implies that the discount to the price overcharge may actually be negative, i.e., the plaintiff may actually incur damages that are *larger* than the price overcharge. A passing-on defense may therefore no longer necessarily be justified.

To see this, we follow the same approach as in the Bertrand case and rewrite firm 1's profit change (22), after substituting firm 1's first-order condition from (18), substituting the pass-on expression (20), and performing the required implicit differentiations  $\frac{\partial q_1^*(\bar{c}, c_i)}{\partial \bar{c}}$  and  $\frac{\partial q_1^*(\bar{c}, c_i)}{\partial c_i}$  on (21). This gives:

$$(23) \quad d\pi_1 = - \left( 1 - \left( \frac{2 - \rho s_1}{N + 1 - \rho} N_I - 1 \right) \right) q_1 dc_1.$$

Equation (23) implies that the price overcharge  $(-q_1 dc_1)$  should be discounted by the amount  $\frac{2 - \rho s_1}{N + 1 - \rho} N_I - 1$ . It is easy to see that this discount is not necessarily positive, i.e., the pass-on effect may be fully dominated by the output effect. For example, under linear demand ( $\rho = 0$ ) the discount is negative if and only if the number of  $N_I < \frac{N+1}{2}$ . As another example, under constant and unitary elasticity demand ( $\epsilon = 1$  and  $\rho = 1 + \frac{1}{\epsilon} = 2$ ) the discount is negative if and only if  $N_I < \frac{N-1}{2(1-s_1)}$ . Intuitively, in the Cournot model negative discounts to the price overcharge may arise and invalidate the passing-on defense because the unaffected firms respond aggressively by expanding their output when the plaintiff and the other affected firms reduce output after the cost increase. These aggressive output responses may make the output effect fully dominate the pass-on effect. We therefore have:

*Proposition 3.* Consider a Cournot industry where cost increases for a group of firms  $I$  only, including the plaintiff firm 1. The appropriate discount to the

price overcharge suffered by plaintiff firm 1 may be positive or negative, and is given by

$$(24) \quad \text{discount} = \frac{2 - \rho s_1}{N + 1 - \rho} N_I - 1 \leq 10$$

An adjusted passing-on defense is therefore not necessarily justified.<sup>21</sup>

The discount formula (24) is written in terms of the demand curvature condition  $\rho$ . Using (20), it is however also possible to rewrite it in terms of the pass-on rate  $\tau$ . This gives:

$$\begin{aligned} \text{discount} &= (1 - s_1) \frac{N_I}{N} \tau - (1 - Ns_1) \left( 1 - \frac{N_I}{N} \tau \right) \\ &\quad - Ns_1 \left( 1 - \frac{N_I}{N} \right). \end{aligned}$$

This formula may be preferred if  $\rho$  is difficult to observe and instead an estimate of  $\tau$  is available. This is also how we expressed the discount formulas for the Bertrand model or for the symmetric models with a common cost increase.<sup>22</sup>

Because of the Cournot assumption  $1 - \rho s_i \geq 0$  for all  $i$ , we have  $\frac{2 - \rho s_1}{N + 1 - \rho} > 0$ . This immediately implies that the discount (24) increases as the number of affected firms  $N_I$  increases. It is not obvious, however, how many affected firms are required for the discount to become positive and a passing-on defense to be justified. This depends on the plaintiff's market share  $s_1$ , on the number of firms  $N$  and especially on the curvature of demand  $\rho$ , of which both the sign and the magnitude are unknown and difficult to measure empirically (since it captures a second-order property of the demand curve). We can nevertheless show:

*Proposition 4.* (a) In a Cournot industry with a common cost increase ( $N_I = N$ ), the discount is positive and hence an adjusted passing-on defense is justified unless  $\rho < -(N - 1)$  and  $s_1 < \frac{1}{N} - \frac{N-1}{N} \frac{1}{(-\rho)}$ .

(b) In a Cournot industry with a cost increase to the plaintiff only ( $N_I = 1$ ), the discount is negative and hence an adjusted passing-on defense is not justified unless  $\rho > (N - 1)$  and  $s_1 < \frac{1}{N} - \frac{N-1N-\rho}{N} \frac{1}{\rho}$ .

*Proof.* See the Appendix. ■

<sup>21</sup> Furthermore, the discount may be greater than one, if demand is sufficiently convex.

<sup>22</sup> Note that if the cost increase applies to all firms  $N_I = N$ , and the plaintiff has a symmetric market share  $s_1 = \frac{1}{N}$ , the second and third terms vanish so that the discount reduces to our earlier symmetric Cournot formula (10) (with  $\theta = 1$ ).

Proposition 4 provides easy to interpret necessary and sufficient conditions under which the passing-on defense is justified after a common cost increase ( $N_I = N$ ) and not justified after a cost increase to the plaintiff only ( $N_I = 1$ ). While a cost increase to the plaintiff only is clearly not representative for most cartels, it serves as a benchmark to stress that a passing-on defense against a Cournot plaintiff is only valid if a sufficiently large number of firms is affected by the cartel.

Proposition 4 can be simplified to the following possible sufficient conditions:

*Corollary 3.* For the Cournot industry suppose that one of the following conditions applies: (i)  $-(N - 1) \leq \rho \leq N - 1$  or equivalently  $\frac{1}{2} < \tau < \frac{N}{2}$ ; or (ii)  $s_1 \geq \frac{1}{N}$ . An adjusted passing-on defense is then always justified after a common cost increase ( $N_I = N$ ) and never justified after a cost increase to the plaintiff only ( $N_I = 1$ ).

*Proof.* The demand curvature condition  $-(N - 1) \leq \rho \leq N - 1$  follows immediately from Proposition 4, and is equivalent to the condition on the pass-on rate  $\frac{1}{2} \leq \tau \leq \frac{N}{2}$  by (20). The market share condition  $s_1 \geq \frac{1}{N}$  also follows immediately, since both market share thresholds in Proposition 4 are below  $\frac{1}{N}$ . ■

The demand curvature condition on  $\rho$  (or the equivalent pass-on rate condition) is satisfied for a wide range of demand functions, including linear and exponential demand, but not necessarily under constant elasticity demand. The market share condition generalizes our earlier result of Corollary 2 that the passing-on defense is justified in a symmetric Cournot model with a common cost increase:<sup>23</sup> this continues to be true in an asymmetric Cournot model as long as the plaintiff has a higher than average market share. In sum, under a wide variety of circumstances the passing-on defense is justified when all firms are affected by the cost increase, and not justified when only the plaintiff is affected. This shows the key importance of assessing how many firms have been affected by the cost increase before resorting to the passing-on defense in a Cournot industry.

*Specific functional forms of demand.* A more concrete picture of the discount formula (24) and our subsequent results emerges from specific functional forms of demand. Consider Genesove and Mullin's [1998] demand specification  $Q = \beta(\alpha - p)^\gamma$ , according to which the demand curvature is  $\rho = \frac{\gamma-1}{\gamma}$ . This specification nests various special demand functions with an

<sup>23</sup> This is the special case for which  $N_I = N$  and  $s_i = \frac{1}{N}$  for all  $i$ .

TABLE II  
DISCOUNT TO THE COST EFFECT OF THE CARTEL: COURNOT COMPETITION

Unaffected firms	Plaintiff's market share: $s_1 = 10\%$			Plaintiff's market share: $s_1 = 50\%$		
	Number of firms in the downstream market ( $N$ )					
	2	6	10	2	6	10
linear demand ( $\rho = 0$ , so $\tau = \frac{N}{N+1}$ )						
0	33%	71%	82%	33%	71%	82%
1	<b>-33%</b>	43%	64%	<b>-33%</b>	43%	64%
5		<b>-71%</b>	-9%		<b>-71%</b>	-9%
9			<b>-82%</b>			<b>-82%</b>
quadratic demand ( $\rho = \frac{1}{2}$ , so $\tau = \frac{N}{N+1/2}$ )						
0	56%	80%	86%	40%	62%	67%
1	<b>-22%</b>	50%	67%	<b>-30%</b>	35%	50%
5		<b>-70%</b>	-7%		<b>-73%</b>	-17%
9			<b>-81%</b>			<b>-83%</b>
exponential demand ( $\rho = 1$ , so $\tau = 1$ )						
0	90%	90%	90%	50%	50%	50%
1	<b>-5%</b>	58%	71%	<b>-25%</b>	25%	35%
5		<b>-68%</b>	-5%		<b>-75</b>	-70%
9			<b>-81%</b>			<b>-85%</b>
log-linear demand with $\varepsilon = 2$ ( $\rho = \frac{3}{2}$ , so $\tau = \frac{N}{N-1/2}$ )						
0	147%	102%	95%	67%	36%	32%
1	<b>23%</b>	68%	75%	<b>-17%</b>	14%	18%
5		<b>-66%</b>	-3%		<b>-77%</b>	-31%
9			<b>-81%</b>			<b>-87%</b>

Notes: The numbers are based on the discount formula (24) after substituting the relevant demand parameters  $\rho$ . The market shares are as follows: plaintiff = 10% or 50%; other firms: identical share of remaining part. The numbers in bold refer to common cost increases (all firms are insiders).

increasingly convex curvature: linear demand ( $\gamma = 1$ , so that  $\rho = 0$ ), quadratic demand ( $\gamma = 2$ , so that  $\rho = \frac{1}{2}$ ), exponential demand ( $\alpha, \gamma \rightarrow \infty, \frac{\alpha}{\gamma}$  constant, so that  $\rho = 1$ ), and log-linear or constant elasticity demand ( $\alpha = 0$ ,  $\gamma < 0$ , so that  $\rho = 1 + \frac{1}{\varepsilon}$ ). We then have incomplete pass-on ( $\tau < 1$ ) for linear and quadratic demand; complete pass-on ( $\tau = 1$ ) for exponential demand; and more than complete pass-on ( $\tau > 1$ ) for log-linear demand.

Table II computes the discount to the price overcharge for these four demand specifications, for alternative values of the number of firms  $N$ , the number of unaffected firms  $N - N_f$ , and the plaintiff's market share  $s_1$  (either 10% or 50%).<sup>24</sup> Table II confirms our findings summarized in Propositions 3 and 4 and Corollary 3. In contrast to the Bertrand model, the discount is not generally positive. It is, however, positive for a common cost increase (no unaffected firms, on first row of each panel). It decreases as the number of unaffected firms increases and it is almost always negative for a cost increase to the plaintiff only (all firms but the plaintiff are unaffected, bold numbers

<sup>24</sup>The elasticity is irrelevant for the results in all specifications, except under log-linear demand. In that case, we set it equal to 2 so that  $\rho = 1 + \frac{1}{\varepsilon} = \frac{3}{2}$ .

on diagonal).<sup>25</sup> Table II also illustrates how the discount varies in a complex way with the number of competing firms  $N$ , the plaintiff's market share  $s_1$  and especially how this interacts with the demand curvature  $\rho$ . When the plaintiff has a small market share of 10%, the most conservative discounts obtain in the linear demand case, and they increase as demand becomes more convex. The reverse is true however when the plaintiff has a large market share of 50% and the number of firms is sufficiently large (6 or 10).<sup>26</sup> This discussion shows the importance of a robustness analysis in applying the passing-on defense when the demand curvature  $\rho$  is not observed. Alternatively, one may indirectly retrieve  $\rho$  from an empirical estimate of the pass-on rate  $\tau$  and applying the pass-on formula (20).

## VI. EMPIRICAL ILLUSTRATION: THE EUROPEAN VITAMIN CARTEL

In its decision of 21 November, 2001, the European Commission issued large fines to several vitamin producers for participating in a cartel during 1989–1999. Premixing companies were important customers, as they require vitamins in their production of nutritional additives. To quantify their potential damages, it is not relevant to just measure the price overcharge from the cartel. One should also ask whether the premixers were capable of passing on part of this overcharge to their own customers (the compound feed producers) and whether such a passing-on would hurt their sales. To show how our analysis can shed light on this, we calculate discounts to the price overcharge, solely based on information from the public domain. We use two sources of information for the vitamin cartel and the premixing market: the 2001 European Commission's Decision regarding the vitamin cartel, and a 2001 U.K. Competition Commission Report regarding a merger between two vitamin producers (BASF and Takeda Chemicals).

To illustrate the methodology, assume that the premixing market can be described by Bertrand price competition with differentiated products according to the logit demand model of section 5.1. This implies that (17) is the relevant formula for the discount to the price overcharge. Formula (17) requires the following information. First, we need to know the premixers and their market shares. The U.K. Competition Commission Report describes the following premixers and their market shares: Roche, Frank

<sup>25</sup> There is only one case with a positive discount (23%) after a cost increase to the plaintiff, i.e., under the log-linear demand with  $N = 2$ ,  $N_I = 1$  and plaintiff's market share  $s_1 = 0.1$ . In this case, the two possible sufficient conditions of Corollary 7 are violated since (i)  $\rho = \frac{3}{2} > 1$ , and  $s_1 = 0.1 > \frac{1}{2}$ .

<sup>26</sup> Furthermore, for linear and quadratic demand, the discount increases as the number of competing firms  $N$  increases, as in the Bertrand case. This is also true for exponential demand if there is at least one outsider. However, for exponential demand without an outsider, the discount is independent of the number of competitors. Furthermore, for log-linear demand, the discount may actually decrease as competition increases.

TABLE III  
AN ADJUSTED PASSING-ON DEFENSE AGAINST PREMIXERS IN THE VITAMIN CARTEL

	Market share	Required discount to the price overcharge		
		Firms unaffected by the price overcharge		
		—	Roche	Roche and Frank Wright
Roche	26	—	—	—
Frank Wright	30	—	—	—
Trouw	15	90.4	65.5	39.0
Premier	12	90.7	66.3	40.4
Nutec	10	90.8	66.9	41.1
Others	7	91.1	67.7	42.8

Notes: All numbers are percentages. Market shares in first column are averages based on U.K. Competition Commission Report, Ch. 4, p. 83, Table 4.16. The market share of the outside good is set equal to the market share of ‘others’ and shares are subsequently rescaled to add up to 100%. Discounts to Roche and Frank Wright are irrelevant as they are integrated with the vitamin producers.

Wright, Trouw, Premier, Nutec and ‘all others.’ The first column of Table III summarizes the information on their market shares. Second, we need information on the market share of the outside good (the no-purchase alternative). The U.K. Competition Commission report suggests that there are few substitutes for premix (para 4.182). We therefore set the market share of the outside good at a relatively low level. (We choose it to be equal to the market share of all other premixers.)

Finally, we need to know which premixers were affected by the cartel. Two premixers are vertically integrated with vitamin producers and may therefore not have been affected: Roche throughout the cartel period and Frank Wright since 1997 (as it was acquired by BASF in 1996). In principle, an upstream firm (vitamin producer) would not necessarily want to favour its own downstream business (premixing unit), since this might entail productive or demand distortions. In the case of a cartel, the vertically integrated firms might however find such favouring advantageous as it would provide an opportunity to cheat from the cartel. However, the European Commission Decision describes in some detail (e.g., para 225) that the cartel members were aware of this problem. They had a quota system which included vitamin sales of the vertically integrated firms to their own downstream subsidiaries. This is further supported by some empirical evidence: Frank Wright did not see its premix market share increase after it was acquired by BASF. While there are therefore no compelling reasons to think that Roche and Frank Wright were unaffected by the cartel, we allow for this possibility by considering three scenarios. In the first scenario all premixers were affected by the overcharge, in the second Roche was not affected and in the third both Roche and Frank Wright were unaffected.

Table III shows the discounts to the price overcharge as implied by (17). If all premixers are affected (second column), the appropriate discounts to the price overcharge are around 90%. In other words, only around 10% of the

cartel price overcharge is then suffered as damages to premixers. In contrast, if Roche's premixing subsidiary were not affected, the discounts would drop to about 66–68%. Intuitively, this is because the premixers would be more constrained in passing on the price overcharge as they would lose business to Roche. Finally, if both Roche and Frank Wright would not be affected, the discounts would drop to about 39–43%.

These calculations are largely based on market shares and assumptions about competition in the premixing market. A more complete analysis would aim to estimate directly the extent of pass-on, based on historical information about vitamin prices and premix prices. The estimated degree of pass-on could then be inserted as  $\sum_{i \in I} T_i$  in (17), so that market shares are only necessary for computing the adjustments for the output effect. If such information were not available, it would be warranted to perform an extensive further sensitivity analysis regarding the premixing market, e.g., by considering alternative models of competition.

## VII. THE CARTEL'S TOTAL HARM

Our analysis has so far exclusively looked at the cartel's effects on the profits of one direct purchaser. In a recent paper, Basso and Ross [2007] take a different focus and analyze the total harm of the cartel. This is the harm to the affected parties, i.e., all direct purchasers and their consumers. They show that the total harm is larger than the traditional price overcharge, especially when the direct purchasers have a lot of market power. Their analysis is complicated by the fact that they allow for a large price overcharge. Based on our differential approach, which looks at 'small' price overcharges, we now show that the total harm exceeds the price overcharge by an amount that is equal to our output effect.

We return to the case of a common cost increase of section 4, but now consider the cartel's effect on all direct purchasers and on their consumers. As before, total industry demand when all firms set the same price  $p$  is  $Q = Q(p)$ . Furthermore, let aggregate consumer surplus be  $v(p)$ . The downstream industry equilibrium price as a function of the common marginal cost  $c$  is again  $p = p^*(c)$ . The affected parties' surplus as a function of marginal cost  $c$  is the sum of downstream industry profits  $\Pi(c)$  and aggregate consumer surplus  $v(p^*(c))$ :

$$\begin{aligned} S(c) &= \Pi(c) + v(p^*(c)) \\ &= (p^*(c) - c)Q(p^*(c)) + v(p^*(c)). \end{aligned}$$

Note that because of our focus on the direct purchasers and consumers, this surplus function does not include the cartel's profits, so it does not represent total welfare.

The cartel's total harm is the change in the affected parties' surplus due to the cartel's overcharge or cost increase  $dc$ :

$$\begin{aligned} dS = & \left( -Q + Q \frac{\partial p^*(c)}{\partial c} + (p - c) \frac{\partial Q(p)}{\partial p} \frac{\partial p^*(c)}{\partial c} \right) dc \\ & + \frac{\partial v(p)}{\partial p} \frac{\partial p^*(c)}{\partial c} dc. \end{aligned}$$

There are two components. First, the cartel's effect on direct purchasers consists of the price overcharge and the pass-on and output effects. This parallels our previous analysis of the purchaser plaintiff's profit effects, now at the aggregate industry level; see (3) in section 4. Second, the effect on consumers is the pass-on effect, as transferred by the cartel's direct purchasers. Applying the aggregate version of Roy's identity,  $Q = -\frac{\partial v(p)}{\partial p}$ , and using our earlier defined price elasticity of demand  $\varepsilon$ , pass-on rate  $\tau$  and competition intensity parameter  $\lambda$ , the cartel's total harm can be written as:

$$(25) \quad \begin{aligned} dS = & -(1 - (1 - \lambda)\tau)Qdc - \tau Qdc \\ = & -(1 + \lambda\tau)Qdc. \end{aligned}$$

The final consumers are hurt by the extent of pass-on  $\tau$ , but this is merely a transfer from the cartel's purchasers so it cancels out in the second line of (25). The total harm is therefore the price overcharge, plus a percentage premium  $\lambda\tau$ . In fact, this premium is equal to the output effect that was also used in the downward adjustment of the discount when applying a passing-on defense to the purchaser plaintiff. We therefore have:

*Proposition 5.* Consider a symmetric industry with a common cost increase due to the cartel. The total harm from the cartel consists of the price overcharge to the downstream industry, plus a percentage premium of  $\lambda\tau$ . This premium is equal to the output effect.

The result that the total harm from the cartel is larger than the price overcharge is consistent with Basso and Ross [2007]. We show that this premium (or multiplier, as they call it) is equal to the output effect and can be nicely written in terms of the pass-on rate  $\tau$  and our competition intensity parameter  $\lambda$ . Interestingly, an adjusted passing-on defense against the purchaser plaintiffs may therefore actually turn against the defendant, since the evidence required to adjust for the output effect in the passing-on defense may also be used to demonstrate by how much the cartel's total harm exceeds the price overcharge.

We can also briefly relate our approach to two other recent papers. Boone and Müller [2008] take as given the total harm from the cartel, to focus on the question how this total harm is distributed between the direct purchasers

and final consumers. If firms are symmetric, it follows from (25) that the consumer harm share  $CHS$  is simply:

$$(26) \quad CHS = \frac{\tau Qdc}{(1 + \lambda\tau)Qdc} = \frac{1}{1/\tau + \lambda}.$$

Boone and Müller's formula in their proposition 1 reduces to (26) when firms are symmetric. Intuitively, consumers tend to suffer a greater share in total harm (relative to direct purchasers) if the pass-on rate  $\tau$  is high and if the direct purchasers' market power  $\lambda$  is small.

Han, Schinkel and Tuinstra [2008] consider total harm when there are multiple layers of indirect purchasers between the direct purchasers and the final consumers. It is straightforward to generalize Proposition 5 to incorporate multiple layers in our framework. This gives the same total harm formula (25), where  $\lambda$  should be reinterpreted as the overall profit margin of direct and indirect purchasers (adjusted for the elasticity), and  $\tau$  as the combined pass-on rate of direct and indirect purchasers.<sup>27,28</sup>

*Policy options.* We can apply this framework to consider two key policy questions in private enforcement of cartel legislation. First, should a passing-on defense against direct purchasers be allowed, and if so, should it be adjusted for the output effect? Second, should final consumers (or other indirect purchasers) have legal standing to obtain compensation? These questions are relevant both from the perspective of *compensation* of the direct purchasers and consumers and from the perspective of *deterrence*, i.e., the liability of the defendants.

Table IV shows the effects on the different parties of the various policy options. For example, the top left cell shows what happens to direct purchasers and final consumers if no passing-on defense is allowed and if final consumers have no legal standing, as is currently the case in several U.S.

<sup>27</sup> To see this, consider two instead of one downstream layers, with common prices at all layers. The cartel charges a price  $c$  to the direct downstream layer 1, which charges a price  $p^1$  to the second, indirect downstream layer 2, which in turn sells at a price  $p^2$  to final consumers. Layer 1 and layer 2's industry profits are, respectively,  $\Pi^1(c) = (p^1(c) - c)Q(p^2(p^1(c)))$  and  $\Pi^2(c) = (p^2(p^1(c)) - p^1(c))Q(p^2(p^1(c)))$ . Consumer surplus is  $v(p^2(p^1(c)))$ . Differentiate total downstream surplus  $S(c) = \Pi^1(c) + \Pi^2(c) + v(p^2(p^1(c)))$  with respect  $c$  to obtain

$$\frac{dS}{dc} = -(1 + \lambda^2\tau^2\tau^1)Q,$$

where  $\tau^1 = dp^1/dc$  and  $\tau^1 = dp^2/dp^1$  are layer 1 and 2's pass-on rates, and  $\lambda^2 = \varepsilon(p^2 - c)/p^2$  is the conduct parameter summed over both layers 1 and 2. This generalizes (25), where the pass-on rate is now the product of the pass-on rates of both layers 1 and 2.

<sup>28</sup> The change in total welfare, or deadweight loss, can also be derived. This requires adding the change in the cartel's profits to the total harm  $dS$ . Let  $\tilde{\lambda}$  denote the cartel's competition parameter in the absence of the cartel (the elasticity-adjusted profit margin as a fraction of consumer price  $p$ ). It can be verified that the cartel's profit increase is  $(1 - \tilde{\lambda})\tau Qdc$ , so the cartel can generally not appropriate all of the price overcharge gains  $Qdc$ . Hence, the change in total welfare or deadweight loss equals  $-(\lambda + \tilde{\lambda})\tau Qdc$ .

TABLE IV  
COMPENSATION AND LIABILITY UNDER ALTERNATIVE POLICY OPTIONS

passing-on defense?	affected party	final consumers legal standing?	
		no	yes
unadjusted (no account for output effect)	direct purchasers	$Qdc$ (unjust enrichment)	$Qdc$ (unjust enrichment)
	final consumers	0 (unjust impoverishment)	$\tau Qdc$ (correct compensation)
	total	$Qdc$ (underliability)	$(1 + \tau)Qdc$ (overliability)
	direct purchasers	$(1 - \tau)Qdc$ (unjust impoverishment)	$(1 - \tau)Qdc$ (unjust impoverishment)
	final consumers	0 (unjust impoverishment)	$\tau Qdc$ (correct compensation)
	total	$(1 - \tau)Qdc$ (underliability)	$Qdc$ (underliability)
	direct purchasers	$(1 - (1 - \lambda)\tau)Qdc$ (correct compensation)	$(1 - (1 - \lambda)\tau)Qdc$ (correct compensation)
	final consumers	0 (unjust impoverishment)	$\tau Qdc$ (correct compensation)
	total	$(1 - (1 - \lambda)\tau)Qdc$ (underliability)	$(1 + \lambda\tau)Qdc$ (correct liability)

states. The advantage of such a policy is simplicity since it is only necessary to estimate the price overcharge and not to measure the pass-on and output effects. However, there is no correct compensation. The direct purchasers experience ‘unjust enrichment’: they are compensated proportional to the full overcharge (an amount of  $Qdc$ ) although they can pass on part of the overcharge (so that the correct compensation would be  $(1 - (1 - \lambda)\tau)Qdc$ ). Similarly, the final consumers suffer from ‘unjust impoverishment’ as they get nothing even though the direct purchasers passed on part of the overcharge. Finally, there is insufficient liability of the defendant, because the total amount to be paid ( $Qdc$ ) is less than the total harm  $(1 + \lambda\tau)Qdc$ .

The other cells can be interpreted in a similar way. For each policy option one can verify whether the direct purchaser and final consumers get compensated too much or too little (first and second row of each cell), and whether the defendant pays a total amount that corresponds to the total harm. The general conclusion is that compensation and liability are only correct under an adjusted passing-on defense and with legal standing to final consumers (bottom right cell). The policy maker must therefore trade off economically sound compensation and liability against informational and computational simplicity.

## VIII. CONCLUDING DISCUSSION

We have developed a general economic framework to assess cartel damages to a purchaser plaintiff, starting from the anticompetitive price overcharge (or cost effect) as the commonly used basis. We have identified the circumstances under which an adjusted passing-on defense against the purchaser plaintiff is justified. This defense takes into account that any pass-on of the price

overcharge by the plaintiff may subsequently also lead to a reduction in its output. We note, however, that a proper account of the output effect in the passing-on defense may actually turn against the defendant, when one considers the cartel's total harm (i.e., including the effect on final consumers).

Incorporating the output effect in the passing-on defense raises the informational requirements only moderately. For a wide variety of cases, we obtain formulas to discount the price overcharge that depend on observable variables for the purchaser plaintiff's industry. They naturally lead to two empirical approaches. The first is a reduced-form approach and relates most closely to a traditional pass-on analysis. It entails estimating the appropriate pass-on rate (firm-specific or industry-wide) and then adjusting that pass-on rate based on our derived discount formulas for alternative industries.<sup>29</sup> The second approach is the structural approach. This requires substituting the pass-on rate out of the discount formulas, and then estimating all relevant supply and demand parameters entering the discount formula.<sup>30</sup> We illustrated this second approach with the European vitamin cartel.

Our analysis is particularly timely in light of the recent recommendations of the U.S. Antitrust Modernization Commission and the efforts by the European Commission to stimulate private cartel damages claims. Two key policy questions are whether a passing-on defense against direct purchasers should be allowed and whether final consumers (or other indirect purchasers) should have legal standing to obtain compensation. The policy maker must trade off economically sound compensation of the affected parties and liability of the defendant against informational simplicity. The option of no passing-on defense and no legal standing of final consumers has the advantage of informational simplicity. It enables focusing on estimating the cartel's price overcharge, for which there is extensive experience including econometric estimation, as reviewed in, e.g., van Dijk and Verboven [2008] or Davis and Garces [2007]. However, it implies incorrect compensation of the affected parties and insufficient liability since the output effect is ignored. In contrast, the alternative option of an adjusted passing-on defense and legal standing of final consumers is more in line with correct compensation and liability. Our analysis suggests that the informational requirements for this alternative option are not insurmountable.

<sup>29</sup> The empirical literature on estimating pass-on rates is very large, and relates to various areas, including the literature on exchange rate pass-through literature, on tax incidence, on price transmission in agricultural economics, and on market power and competition. See Stennek and Verboven [2001] for an overview. A paper of particular interest in our context is by Ashenfelter, Ashmore, Baker and McKerman [1998], showing how to estimate empirically the firm-specific pass-through rate (in the context of evaluating efficiency gains from mergers).

<sup>30</sup> For example, Proposition 4 writes the Bertrand discount (14) in terms of pass-on rates but our subsequent logit example in section 5.1 eliminates the pass-on rate and writes the discount formulas in terms of demand parameters and market shares. Conversely, Proposition 5 writes the Cournot discount formula (24) in terms of a demand curvature parameter and market variables, but we subsequently rewrite it in terms of the pass-on rate and market variables.

## APPENDIX

AI. *The Logit Model*

The potential number of consumers is  $L$ . Each consumer may buy one of the  $N$  differentiated products or the outside good. The demand for product  $i = 1 \dots N$  is  $D_i(\mathbf{p}) = s_i(\mathbf{p})L$ , where  $s_i = s_i(\mathbf{p})$  are the market shares given by

$$s_i(\mathbf{p}) = \frac{\exp(v_i - \alpha p_i)}{1 + \sum_{k=1}^N \exp(v_k - \alpha p_k)}.$$

The market share of the outside good 0 is simply  $s_0(\mathbf{p}) = 1 - \sum_{i=1}^N s_i(\mathbf{p})$ , so that the demand for the outside good is  $D_0(\mathbf{p}) = s_0(\mathbf{p})L$ . The market share derivatives are

$$\begin{aligned}\frac{\partial s_i(\mathbf{p})}{\partial p_i} &= \alpha s_i(1 - s_i) \\ \frac{\partial s_k(\mathbf{p})}{\partial p_i} &= \alpha s_i s_k \quad \text{for } k \neq i.\end{aligned}$$

Using the diversion ratio between firm 1 and firm  $k$ ,

$$\delta_1^k = -\frac{\partial D_k(\mathbf{p})}{\partial p_1} / \frac{\partial D_1(\mathbf{p})}{\partial p_1} = \frac{s_k}{(1 - s_1)},$$

we can apply (14) to write the discount to the overcharge as:

$$(27) \quad \text{discount} = \frac{s_2}{(1 - s_1)} \tau_I^2 + \dots + \frac{s_i}{(1 - s_1)} \tau_I^N.$$

If the pass-on rates are known or estimated, this can be used to calculate the discount. Alternatively, the pass-on rates can be computed by performing comparative statics on the system of first-order conditions defining the Bertrand-Nash equilibrium:

$$p_i - c_i - \frac{1}{\alpha} \frac{1}{1 - s_i} = 0 \quad \text{for all } i.$$

To perform the comparative statics of a cost increase by firm  $i$  on prices, totally differentiate this system with respect to  $p_k$ ,  $k = 1 \dots N$ , and  $c_i$ . The tedious calculations are somewhat similar to Anderson, de Palma and Thisse [1992], pp. 266–267, except that the comparative statics are in cost rather than in quality and that an outside good is included. This results in the following pass-on rates

$$\begin{aligned}\tau_i^i &= \frac{\partial p_i^*(\mathbf{c})}{\partial c_i} = \frac{s_i}{(1 - s_i)^2 + s_i} T_i + \frac{(1 - s_i)^2}{(1 - s_i)^2 + s_i} \\ \tau_i^k &= \frac{\partial p_k^*(\mathbf{c})}{\partial c_i} = \frac{s_k}{(1 - s_k)^2 + s_k} T_i \quad \text{for } k \neq i.\end{aligned}$$

where

$$T_i = \frac{s_i(1 - s_i)^2}{(1 - s_i)^2 + s_i} \left/ \left( s_0 + \sum_{k=1}^N \frac{s_k(1 - s_k)^2}{(1 - s_k)^2 + s_k} \right) \right..$$

Note that  $T_i = \sum_{k=1}^N s_k \frac{\partial p_k^*(\mathbf{c})}{\partial c_i}$ , i.e.,  $T_i$  can be interpreted as the effect of a cost increase of firm  $i$  on the industry price index, using market shares as weights. Inserting the pass-on effects in  $\tau_i^k$ ,  $k = 2 \dots N$  and then in (27), and rearranging gives the following expression

for the discount

$$\text{discount} = \frac{(\sum_{i \in I} T_i) - s_1(1 - s_1)}{(1 - s_1)^2 + s_1}.$$

This can be computed based on information on the market shares of all products including the outside good.

#### AII. Proof of Proposition 4

The assumptions of the Cournot model involve the following inequalities: (i)  $\rho s_1 \leq 1$ , (ii)  $\rho \leq N$ , (iii)  $N > 1$  and (iv)  $0 < s_1 < 1$ . To show the proposition, we have to derive the sign of the discount (24) or equivalently the sign of  $2N_I - N - 1 - \rho(s_1 N_I - 1)$  under (a)  $N_I = N$  and (b)  $N_I = 1$ .

To show (a), we have to show that  $N - 1 - \rho(s_1 N - 1) > 0$ . Consider all possible cases for  $\rho$ . First, if  $\rho > 1$ , then  $N - 1 - \rho s_1 N + \rho \geq N - 1 - N + \rho = \rho - 1 > 0$  by (i). Second, if  $0 \leq \rho \leq 1$  and  $s_1 N - 1 \geq 0$ , then  $N - 1 - \rho(s_1 N - 1) \geq N - 1 - (s_1 N - 1) = N(1 - s_1) > 0$  by (iv). Third, if  $0 \leq \rho \leq 1$  and  $s_1 N - 1 < 0$ , then  $N - 1 - \rho(s_1 N - 1) \geq N - 1 > 0$  by (iii). Fourth, if  $\rho < 0$  and  $s_1 N - 1 \geq 0$ , then  $N - 1 - \rho(s_1 N - 1) \geq N - 1 > 0$  by (iii). Fifth, if  $-(N - 1) \leq \rho < 0$  and  $s_1 N - 1 < 0$ , then  $N - 1 - \rho(s_1 N - 1) \geq N - 1 + (N - 1)(s_1 N - 1) = (N - 1)s_1 N > 0$  by (iii). Finally, if  $\rho < -(N - 1)$  and  $s_1 N - 1 < 0$ , then  $N - 1 - \rho(s_1 N - 1) > 0$  is equivalent with the market share condition  $s_1 > \frac{1}{N} - \frac{N-1}{N} \frac{1}{(-\rho)}$ . This shows that the discount is always positive, unless possibly in the final case, namely if  $\rho < -(N - 1)$  and  $s_1 < \frac{1}{N} - \frac{N-1}{N} \frac{1}{(-\rho)}$ .

To show (b), we have to show that  $1 - N + \rho(1 - s_1) < 0$ . Consider again all possible cases for  $\rho$ . First, if  $\rho \leq 0$ , then  $1 - N + \rho(1 - s_1) \leq 1 - N < 0$  by (iii). Second, if  $0 < \rho \leq 1$ , then  $1 - N + \rho(1 - s_1) < 1 - N + \rho \leq 1 - N + 1 \leq 0$  by (iii). Third, if  $\rho > 1$  and  $s_1 N - 1 \geq 0$ , then  $1 - N + \rho(1 - s_1) < 1 - N + N(1 - s_1) = 1 - s_1 N \leq 0$  by (ii). Fourth, if  $N - 1 > \rho > 1$  and  $s_1 N - 1 < 0$ , then  $1 - N + \rho(1 - s_1) < 1 - N + (N - 1)(1 - s_1) = -(N - 1)s_1 < 0$  by (iii). Finally, if  $\rho > (N - 1)$  and  $s_1 N - 1 < 0$ , then  $1 - N + \rho(1 - s_1) < 0$  is equivalent to the market share condition  $s_1 > \frac{1}{N} - \frac{N-1}{N} \frac{N-\rho}{\rho}$ . This shows that the discount is always negative unless possibly in the final case, namely if  $\rho > (N - 1)$  and  $s_1 < \frac{1}{N} - \frac{N-1}{N} \frac{N-\rho}{\rho}$ .

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# Appendix C

# Structural Analysis of Manufacturer Pricing in the Presence of a Strategic Retailer

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## Abstract

Consumer goods manufacturers usually sell their brands to consumers through common independent retailers. Theoretical research on such channel structures has analyzed the optimal behavior of channel members under alternative assumptions of manufacturer-retailer interaction (Vertical Strategic Interaction). Research in Empirical Industrial Organization has focused on analyzing the competitive interactions between manufacturers (Horizontal Strategic Interaction). Decision support systems have made various assumptions about retailer-pricing rules (e.g., constant markup, category-profit-maximization). The appropriateness of such assumptions about strategic behavior for any specific market, however, is an empirical question. This paper therefore empirically infers (1) the Vertical Strategic Interaction (VSI) between manufacturers and retailer, (2) the Horizontal Strategic Interaction (HSI) between manufacturers simultaneously with the VSI, and (3) the pricing rule used by a retailer.

The approach is particularly appealing because it can be used with widely available scanner data, where there is no information on wholesale prices. Researchers usually have no access to wholesale prices. Even manufacturers, who have access to their own wholesale prices, usually have limited information on competitors' wholesale prices. In the absence of wholesale prices, we derive formulae for wholesale prices using game-theoretic solution techniques under the specific assumptions of vertical and horizontal strategic interaction and retailer-pricing rules. We then embed the formulae for wholesale prices into the estimation equations. While our empirical illustration is using scanner data without wholesale prices, the model itself can be applied when wholesale prices are available.

Early research on the inference of HSI among manufacturers in setting wholesale prices using scanner data (e.g., Kadiyali et al. 1996, 1999) made the simplifying assumption that retailers charge a constant margin. This assumption enabled them to infer wholesale prices and analyze competitive interactions between manufacturers. In this paper, we show that this model is econometrically identical to a model that measures retail-price coordination across brands. Hence, the inferred cooperation among manufacturers could be exaggerated by the coordinated pricing (category management) done by the retailer. We find empirical support for this argument. This highlights the need to properly model

and infer VSI simultaneously to accurately estimate the HSI when using data at the retail level.

Functional forms of demand have been evaluated in terms of the fit of the model to sales data. But recent theoretical research on channels (Lee and Staelin 1997, Tyagi 1999) has shown that the functional form has serious implications for strategic behavior such as retail passthrough. While the logit and linear model implies equilibrium passthrough of less than 100% (Lee and Staelin call this Vertical Strategic Substitute (VSS)), the multiplicative model implies optimal passthrough of greater than 100% (Vertical Strategic Complement (VSC)). Because passthrough rates on promotions have been found to be below or above 100% (Chevalier and Curhan 1976, Armstrong 1991), we empirically test the appropriateness of the logit (VSS) and the multiplicative (VSC) functional form for the data.

We perform our analysis in the yogurt and peanut butter categories for the two biggest stores in a local market. We found that the VSS implications of the logit fit the data better than the multiplicative model. We also find that for both categories, the best-fitting model is one in which (1) the retailer maximizes category profits, (2) the VSI is Manufacturer-Stackelberg, and (3) manufacturer pricing (HSI) is tacitly collusive. The fact that the retailer maximizes category profits is consistent with theoretical expectations. The inference that the VSI is Manufacturer-Stackelberg reflects the institutional reality of the timing of the game. Retailers set their retail prices after manufacturers set their wholesale prices. Note that in the stores and product categories that we analyze, the two manufacturers own the dominant brands with combined market shares of about 82% in the yogurt market and 65% in the peanut butter market. The result is also consistent with a balance of power argument in the literature. The finding that manufacturer pricing is tacitly collusive is consistent with the argument that firms involved in long-term competition in concentrated markets can achieve tacit collusion.

Managers use decision support systems for promotion planning that routinely make assumptions about VSI, HSI, and the functional form. The results from our analysis are of substantive import in judging the appropriateness of assumptions made in such decision support systems.

(*Structural Models; Horizontal Strategic Interaction; Vertical Strategic Interaction; Retailer Pricing; Promotional Planning; New Empirical Industrial Organization*)

STRUCTURAL ANALYSIS OF MANUFACTURER PRICING IN THE PRESENCE OF A STRATEGIC RETAILER

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## 1. Introduction

Manufacturers of most consumer goods sell their brands to consumers through common independent retailers (e.g., supermarkets and convenience stores for grocery products, department stores, specialty stores for consumer electronics, sporting goods, etc.). There has been substantial theoretical research on such channel structures (e.g., McGuire and Staelin 1983, Choi 1991, Lee and Staelin 1997). This stream of research has analyzed the optimal behavior of channel members under alternative assumptions about vertical strategic interactions between manufacturers and retailers. Researchers of the new empirical industrial organization (e.g., Kadiyali et al. 1996, 1999) have studied the competitive interactions between manufacturers (horizontal strategic interaction). Decision support systems for promotion planning make assumptions about the pricing rules used by retailers (e.g., Silva-Risso et al. 1999 assume constant margin, Tellis and Zufryden 1995 assume category-profit maximization). The appropriateness of such assumptions for any specific market is an empirical question. Our goal in this paper is to empirically infer (1) the vertical strategic interaction (VSI) between manufacturers and retailer, (2) the horizontal strategic interaction (HSI) between manufacturers simultaneously with the VSI, and (3) the pricing rule used by a retailer.

The approach in this paper is particularly appealing because it can be used with widely available scanner data, where there is no information on wholesale prices. Researchers usually have no access to wholesale prices. Manufacturers have access to their own wholesale prices, but usually have only limited information on competitors' wholesale prices. In the absence of wholesale prices, we derive formulae for wholesale prices using game-theoretic solution techniques under the specific assumptions of vertical and horizontal strategic interaction, demand functional form, and retailer pricing rules. We then embed the formulae for wholesale prices into the estimation equations.<sup>1</sup> While our empirical illustration is using

<sup>1</sup>It is important to note that the derivation methods used to solve for wholesale and retail prices in this paper are different from approaches used in theoretical papers. Theoretical models derive the optimal wholesale and retail prices (and the resulting market

scanner data without wholesale prices, the model itself is easily applicable to the situation where wholesale prices are available by using the derived formulae for wholesale prices as additional estimation equations in the model.

### Relationship with Previous Research

For a quick overview of the relative contribution of this paper, we compare related papers in the literature in Table 1.

Several papers in the new empirical industrial organization (NEIO) tradition have attempted to infer competitive interactions underlying pricing behavior among manufacturers (HSI) using national-level data (for example, see Roy et al. 1994 and Kadiyali 1996). In these papers, retailer behavior is not modeled. One justification for this is that the focus is on competition at the national level. Furthermore, any particular retailer's strategic behavior will be lost in the data aggregation across retailers, and hence, is irrelevant for the level at which the analysis is done.

Because manufacturers do tailor their marketing mix to local market conditions (Manning et al. 1998, Nichols 1987), NEIO researchers have recently shifted their focus to analyzing HSI among manufacturers in local markets using scanner data. But at this local level, retailer strategic behavior can have a significant influence on a manufacturer's price-setting behavior. Therefore, retailer's interaction with manufacturers (VSI) needs to be accounted for. A further complication when using scanner data is that wholesale prices are unavailable to the researcher. As a result, to analyze manufacturer wholesale-pricing behavior, the wholesale prices need to be inferred from the data.

Kadiyali et al. (1996, 1999) infer wholesale prices by making a simplifying assumption about the VSI. They assume that the retailer is nonstrategic and charges an exogenous constant margin. This assump-

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shares) based on the parameters of the demand model (which are assumed to be completely known with no econometric error). An econometric model, however, is used to estimate the parameters of the demand model assuming that the observed market shares and retail prices are an outcome of optimal firm behavior conditional on the underlying parameters of the demand model.

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**Table 1 Positioning Against Related Research**

	Manufacturer-Manufacturer Interaction	Manufacturer-Retailer Interaction	Retailer Pricing Rule	Demand Functional Form	Wholesale Price Information Available
Roy et al. (1994); Kadiyali (1996)	Estimated	NA	NA	Linear	NA
Kadiyali et al. (1996, 1999)	Estimated	Manufacturer Stackelberg	Constant margin	Linear	No
Besanko et al. (1998)	Bertrand assumed	Vertical Nash	Category profit	Logit	No
Cotterill and Putsis (2001)	Bertrand assumed	Manufacturer Stackelberg, vertical Nash, and retailer Stackelberg models (with Bertrand among manufacturers)	Category profit	Linear, estimates LADs without structural pricing equations	No
Kadiyali et al. (2000)	Cannot separately identify from reaction to retailer	1. CV estimated 2. Manufacturer Stackelberg, vertical nash, and retailer Stackelberg models (but with Bertrand among manufacturers)	Category profit	No	Yes
Sudhir (2001; this paper)	Estimated	Manufacturer Stackelberg, vertical Nash	Category profit, brand profit, constant margin	Logit (VSS), Multiplicative (VSC)	No

tion implies that wholesale prices can be obtained by scaling down retail prices by a constant factor. These researchers have found that manufacturer pricing (HSI) is more cooperative than Bertrand price competition. In this paper, we show that these models (with retailer assumed to charge a constant margin) are econometrically indistinguishable from a model that simply measures the extent of price coordination across brands by a strategic retailer. This observation raises the question as to whether the estimated level of cooperation among manufacturers could just be coordinated pricing (category management) by the retailer. It, therefore, highlights the need to properly model and infer VSI simultaneously in order to accurately estimate the HSI when using data at the retail level.

In this paper, we investigate competitive behavior among manufacturers by allowing for other plausible manufacturer-retailer interaction and infer the interaction that best fits the data. We allow for two types of VSI between the manufacturers and the retailer: (1) manufacturers as Stackelberg leaders and (2) vertical Nash interaction. We also allow for alternative retailer pricing rules: (1) category profit maximization, (2)

brand profit maximization, and (3) constant margins. Using game-theoretic analysis, we infer wholesale prices conditional on observed retail prices, sales, and other exogenous variables under each of the above assumptions. This enables us to analyze competition among manufacturers (HSI) under alternative assumptions about the VSI.

Besanko et al. (1998) (hereafter referred to as BGJ) focus on the importance of accounting for the endogeneity of pricing decisions by manufacturers and retailers to obtain unbiased estimates for a logit model using aggregate data. In contrast to our emphasis on inferring the strategic behavior of market participants, they assume (1) that manufacturers and the retailer make simultaneous pricing decisions, i.e., they assume that VSI is vertical Nash, (2) that the retailer does category management by maximizing total profits from the category, and (3) that the HSI among manufacturers is Bertrand competition.

Other contemporaneous research has addressed some of the issues that we discuss in this paper. Kadiyali et al. (2000) measure the balance of power between manufacturers and retailer by measuring the share of channel profits. Although they model both

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the HSI between manufacturers and the VSI between manufacturers and retailer, their econometric model does not permit one to identify the HSI between manufacturers (an issue of key interest in this paper).<sup>2</sup> Another key difference is that their technique is applicable only when researchers have access to wholesale price data.

Cotterill and Putsis (2001) also test for the manufacturer Stackelberg and vertical Nash VSI between manufacturers and retailers without wholesale price data. They also test for constant margin and category-profit-maximizing behavior by the retailer. They analyze a number of product categories and find support for both vertical Nash and manufacturer Stackelberg interaction. However, they generally reject the constant margin assumption. In contrast to our paper, they assume a linear model of demand, assume that HSI between manufacturers is Bertrand, and do not test for brand-profit-maximizing behavior by the retailer.<sup>3</sup>

In summary, this is the first paper to simultaneously infer both HSI and VSI in a channel. The technique can be applied even in the absence of wholesale price data. Methodologically, a key difference with respect to Cotterill and Putsis (2001) is that they derive their supply-side pricing equations similarly to theoretical researchers, by solving for optimal wholesale and re-

<sup>2</sup>We note that Kadiyali et al. (2000) estimate conjectural variations (CVs) for VSI and, therefore, do not impose the specific restriction of leader-follower behavior. Estimating CVs, however, does not necessarily make the model more flexible, because the CV measures reactions as a constant across all periods, while the derived optimal reaction in a leader-follower model (that we use here) is flexible to accommodate changes from period to period based on changes in demand characteristics (a realistic assumption). Further research is needed on the appropriateness of the two methods. They also test specific models such as manufacturer Stackelberg, vertical Nash, etc., but, unlike the author of this paper, they assume that the HSI is Bertrand when they test those models. We also note that in the absence of wholesale price data, a CV cannot be estimated for the VSI. The specific assumption about VSI (leader-follower, vertical Nash) is necessary to estimate the model without wholesale price data.

<sup>3</sup>They also estimate an LA-AIDS model, but without the structural pricing equations. Hence it is not possible to choose among the different VSI using the LA-AIDS model.

tail prices in terms of a deterministic demand model.<sup>4</sup> In this paper, we recognize that observed market shares include a demand-side econometric error that is known to both firms and consumers, and therefore will affect retail and wholesale passthrough differently under different types of VSI and HSI. By explicitly deriving the equations in terms of observed market shares, we account for the impact of demand-side econometric error on retail and wholesale passthrough in a manner consistent with the theoretical structure of the specific model being tested, leading to a more complete structural specification of the econometric model.

#### **Appropriateness of Demand Functional Form**

While functional forms of demand have been evaluated in terms of the fit of the model to sales data, recent game-theoretic research on channels (Lee and Staelin 1997, Tyagi 1999) has shown that the functional form of demand has serious implications for strategic behavior such as retail passthrough. While the logit and linear model implies equilibrium passthrough of less than 100% (Lee and Staelin call this vertical strategic substitute (VSS)), the multiplicative model implies optimal passthrough of greater than 100% (vertical strategic complement (VSC)). Since passthrough rates on promotions have been found to be below or above 100% (Chevalier and Curhan 1976, Armstrong 1991), a functional form with the VSC property may be appropriate for categories that have retail passthrough greater than 100%, while a functional form with the VSS property may be appropriate if the passthrough is less than 100%. In this paper, we therefore treat the appropriateness of functional form of demand as an empirical issue and choose from the logit (VSS) or multiplicative (VSC) demand models.<sup>5</sup>

<sup>4</sup>It should be noted that in contrast to our interest in inferring the VSI and HSI, the primary focus of Cotterill and Putsis was to test specific models in the theoretical literature on channels. Hence their use of deterministic demand models was guided by the theoretical literature. Kadiyali et al. (2000) also use the deterministic demand model approach when they test specific VSI such as the Stackelberg or Nash interactions.

<sup>5</sup>We thank an anonymous reviewer for suggesting the empirical analysis of demand functional forms. A simple explanation for

In summary, we choose from the following strategic interactions and demand models:

- (1) Vertical strategic interaction: manufacturer Stackelberg and vertical Nash;
- (2) Horizontal strategic interaction: Bertrand, tacit collusion. We also estimate a continuous conjectural variation (CV) parameter<sup>6</sup>;
- (3) Retailer pricing rule: category-profit-maximization, brand-profit-maximization, constant markup;
- (4) Demand functional form: logit, multiplicative.

Section 2 describes the model. Section 3 describes the data, the estimation procedure, and the results. Section 4 concludes with a discussion of limitations of the model and suggestions for future research.

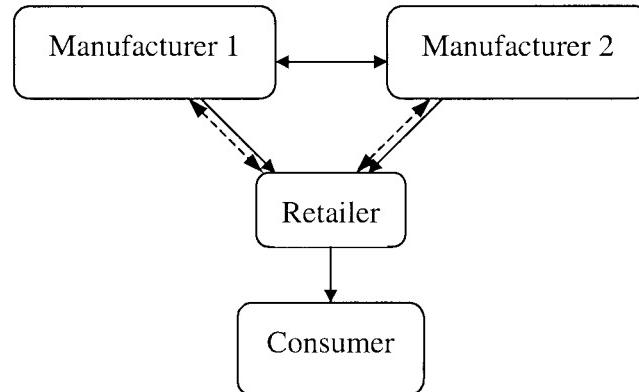
## 2. Model

Figure 1 represents the schematic model of the market that we analyze: Two manufacturers sell through a common retailer to consumers. Consumers make their choices after observing the retail prices. In the manufacturer Stackelberg models, the manufacturers choose wholesale prices first; the retailer chooses retail prices after observing the wholesale prices. In the vertical Nash models, the manufacturers and the re-

passthrough greater than 100% in some categories is that retailers may be using these categories as loss-leaders to drive traffic to the store.

<sup>6</sup>The CV has been used in previous research in the marketing literature (e.g., Kadiyali et al. 1999, Putsis and Dhar 1999) to measure HSI. As the name suggests, CVs were originally interpreted as measures of a player's conjectures about reactions by rivals. This view has been discredited in the theoretical literature because such conjectures cannot be consistent and are not meaningful in a static analysis (Tirole 1988, Carlton and Perloff 1994). Empirical researchers, however, have successfully used CVs as a parameter to measure deviations from Bertrand behavior, without interpreting them as conjectures about reactions between players. See Bresnahan (1989) for the distinction between the theoretical and empirical interpretations of conjectural variations. The menu approach based on theoretical models does not face these criticisms leveled against the CV approach. Briefly, for a strategic variable such as price, zero CV indicates Bertrand competition. Positive and negative CVs indicate more cooperative and more competitive outcomes relative to Bertrand competition, respectively. See Kadiyali et al. (Forthcoming) for a more detailed discussion.

**Figure 1 A Schematic Model of the Market**



tailer choose their prices simultaneously. Manufacturers choose their wholesale prices simultaneously. In the figure, one-sided arrows represent sequential decisions and double-sided arrows indicate simultaneous decisions. The two main assumptions embedded in the figure are that (1) there are two manufacturers in the market and (2) that manufacturers sell through one retailer. We justify both of these assumptions below.

*ASSUMPTION 1. There are two manufacturers in the market.*

We focus our empirical analysis on the two largest brands in the yogurt and peanut butter categories. This is reasonable for our purposes because the two largest brands have a very large market share (82% for yogurt and 65% for peanut butter). Other brands have relatively low market share of less than 10% in this market. Private labels have a minuscule market share in these categories in these stores. Hence, the use of private labels for strategic purposes is not a serious issue as in the studies by Kadiyali et al. (2000) and Putsis and Dhar (1999). While it is possible to extend model development to additional brands, solving for the optimal vertical strategic reactions becomes computationally cumbersome.

*ASSUMPTION 2. Manufacturers sell through one retailer.*

The primary effect of this assumption is that we do not model any effect of retail competition. This may

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be a serious shortcoming when analyzing categories where retail competition is severe. Slade (1995) and Walters and McKenzie (1988), however, have shown evidence of limited retail competition in some categories. Slade reported, based on her interviews of grocery chain managers, that the vast majority of households (over 90%) do not engage in comparison shopping on a week-to-week basis. Most consumers visit the same store each week, and hence most competition seems to take place among brands in the store rather than across stores. Slade also tested this interview-based evidence statistically on the saltine cracker market and found that demand at one store was unaffected by prices in other chains. Walters and Mackenzie examined the impact of loss-leader pricing and other promotions on store sales and profits and concluded that price specials and double-coupon promotions had no significant effect on store traffic. They found that only one of eight loss-leader categories had a significant effect on store traffic. In the structural modeling literature, while analyzing the yogurt category (which is analyzed in this paper), Besanko et al. (1998) and Vilcassim et al. (1999) have also made the assumption of no cross-store competition.

To address the issue of whether the assumption is appropriate for our analysis, we follow Slade in checking whether a store's sales are affected by prices at a competing store. For our analysis we used data from two Every Day Low Price (EDLP) stores, which happen to be the biggest stores in the market. See Section 3 for discussion of the data. We ran a simultaneous equations regression with two linear demand equations for each store. As the two biggest EDLP stores may also face competition from the promotional (High-Low pricing) stores, we also included data from a High-Low store. Together these three stores accounted for 90% of sales in our market. Hence, we had six equations in our estimation. Each brand's sales in a store were regressed against prices of both brands at the same store and other stores.<sup>7</sup> While same store price coefficients were significant and of

<sup>7</sup>In addition to prices of our own and competing stores, we used displays at the same stores and features at our own and competing stores (to see if they affected store traffic). We also tested other functional forms of demand, such as multiplicative and loglinear.

the right sign, other store prices were insignificant in all six equations. Hence, the assumption seems reasonable for the data that we analyze. Essentially, this implies that yogurt or peanut butter prices at competing stores have only a very minor effect on the consumer's decision to visit a particular store. However, it is important to recognize that previous research has shown that detecting store competition requires fairly subtle modeling (Bucklin and Lattin 1992). For our purposes, it appears that retail competition is a second-order effect that is not likely to impact our results.

### Demand

As discussed earlier, we consider two functional forms: the logit demand model with the VSS property and the multiplicative demand model with VSC property. These functional forms have been used widely in the marketing literature: The logit demand model has been used both for modeling household level data (for example, Guadagni and Little 1983) and aggregate market share data (for example, Allenby 1989). Recently, the logit model has been shown to provide similar substantive implications, whether one uses the model at either the aggregate (store) or disaggregate (household) level (Allenby and Rossi 1991, Gupta et al. 1996) under reasonably realistic conditions.<sup>8</sup> The multiplicative demand model is a fairly popular demand model in the literature (for an example, see the SCAN\*PRO-based model of Christen et al. 1997).

**The Logit Model.** The utility for brand  $i$  in period  $t$  for consumer  $j$  is given by

$$\begin{aligned} U_{ijt} &= \beta_{0i} + \beta_ff_{it} + \beta_dd_{it} + \beta_{dp}d_{it}p_{it} + \beta_{fp}f_{it}p_{it} \\ &\quad + \beta_{pi}p_{it} + \xi_{it} + \epsilon_{ijt} \\ &= U_{it} + \epsilon_{ijt} \quad i = 1, 2, \end{aligned} \quad (1)$$

where  $f_{it}$ ,  $d_{it}$ , and  $p_{it}$  are the features, displays, and retail price associated with brand  $i$  in period  $t$ .  $\beta_{0i}$  is

<sup>8</sup>A flexible demand model other than the logit is the LA-AIDS model used by Cotterill et al. (2000). Unfortunately, it is not possible to derive the exact structural supply-side equations for this model as we do in this paper.

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the intrinsic attraction of brand  $i$ , and  $\xi_{it}$  is the unobservable (to the econometrician, but observable to the firm and the consumer) component of utility.  $U_{it}$  is the average utility across consumers for brand  $i$  in period  $t$ . We assume that  $\epsilon_{ijt}$  follows an i.i.d. Type-I extreme value distribution, leading to the logit model.

To allow for the market share of the two inside brands to expand and contract over different periods with the choice of the marketing mix, we allow for nonpurchases (through an outside good) denoted by  $i = 0$ . We normalize the utility of the outside good to zero across periods. That is, we assume  $U_{0t} = 0$ .<sup>9</sup> The market share for each brand is given by

$$s_{it} = \frac{\exp(U_{it})}{1 + \sum_{k=1}^2 \exp(U_{kt})}, \quad i = 0, 1, 2. \quad (2)$$

Therefore, when both brands reduce prices, the total market share of the two inside brands increases vis-à-vis the outside good and vice versa. Note that when the marketing-mix coefficients are the same for both brands the above model reduces to a logit model.

It is easy to see that

$$\begin{aligned} \ln(s_{it}/s_{0t}) &= U_{it} = \beta_{0i} + \beta_f f_{it} + \beta_d d_{it} + \beta_{dp} d_{it} p_{it} \\ &\quad + \beta_{fp} f_{it} p_{it} + \beta_{pi} p_{it} + \xi_{it}, \\ &\quad i = 1, 2. \end{aligned}$$

Therefore, rewriting the demand equation in terms of quantities,

$$\begin{aligned} \ln(q_{it}) &= \ln(q_{0t}) + \beta_{0i} + \beta_f f_{it} + \beta_d d_{it} + \beta_{dp} d_{it} p_{it} \\ &\quad + \beta_{fp} f_{it} p_{it} + \beta_{pi} p_{it} + \xi_{it}, \quad i = 1, 2. \quad (3) \end{aligned}$$

Equation (3) is the demand-side estimation equation. The term  $\xi_{it}$  serves as the error term in the estimation equation. As discussed in Besanko et al. (1998) and Villas-Boas and Winer (1999), these error terms can capture the effects of manufacturer advertising and consumer promotions that we do not explicitly model in this paper.

<sup>9</sup>Modeling the different correlations in  $\epsilon_{ijt}$  between the inside goods and the outside good using a nested logit model would lead to a richer and more flexible formulation. However, this prevents solving for the supply-side estimation equations in closed form.

The first derivatives of market share with respect to prices are

$$\begin{aligned} \frac{\partial s_t}{\partial p_t} &= \begin{pmatrix} \frac{\partial s_{1t}}{\partial p_{1t}} & \frac{\partial s_{2t}}{\partial p_{1t}} \\ \frac{\partial s_{1t}}{\partial p_{2t}} & \frac{\partial s_{2t}}{\partial p_{2t}} \end{pmatrix} \\ &= \begin{pmatrix} \alpha_{1t}s_{1t}(1 - s_{1t}) & -\alpha_{1t}s_{1t}s_{2t} \\ -\alpha_{2t}s_{1t}s_{2t} & \alpha_{2t}s_{2t}(1 - s_{2t}) \end{pmatrix}, \quad (4) \end{aligned}$$

where  $\alpha_{it} = \beta_{dp}d_{it} + \beta_{fp}f_{it} + \beta_{pi}$ .

**The Multiplicative Model.** The multiplicative demand model was

$$q_{it} = a_i p_{it}^{bii} p_{jt}^{bij} f_{it}^{fii} f_{jt}^{fij} d_{it}^{di} d_{jt}^{dij}.$$

For estimation, we used the log-log model, by taking the logs of the above equation on both sides and adding a normal additive error. The derivatives with respect to price for the multiplicative model are well known.

### Retailer Model

We derive the pricing equations for the retailer under different types of VSI for the logit model. For the multiplicative model, the equations can be derived similarly.

For the category-profit-maximizing retailer the objective is to maximize category profits in period  $t$ . Since consumers who buy other than the two brands that we analyze may contribute to retailer profits, we assume that the outside good gives a constant contribution to retailer profit. Denoting the margin from the outside good as  $m_0$ , the retailer objective is given by

$$\Pi_t^R = [(p_{1t} - w_{1t})s_{1t} + (p_{2t} - w_{2t})s_{2t} + m_0 s_{0t}]M_t, \quad (5)$$

where  $p_{1t}$  and  $p_{2t}$  are the retail prices of Products 1 and 2,  $w_{1t}$  and  $w_{2t}$  are the wholesale prices of Products 1 and 2 set by the manufacturers, and  $s_{1t}$  and  $s_{2t}$  are the shares of Products 1 and 2 defined in the demand model (note that  $s_{0t} = 1 - s_{1t} - s_{2t}$  is the share of the outside good), and  $M_t$  is the size of the market. The subscript  $t$  refers to the period  $t$ .

For the retailer maximizing brand profits, the objective is to maximize each brand  $i$ 's profits in period  $t$  without considering the impact of the chosen price

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on the demand and profits from the other brand. The objective is given by

$$\Pi_{it}^R = [(p_{it} - w_{it})s_{it}]M_t, \quad i = 1, 2. \quad (6)$$

Because the retailer is a follower in the manufacturer Stackelberg games, the retailer does not incorporate manufacturer reactions when choosing retail prices. In the vertical Nash game also, the retailer does not incorporate manufacturer reactions, due to the simultaneous nature of the game. Hence, the first-order conditions and the pricing equations are identical for both the manufacturer Stackelberg models and vertical Nash models.

For the retailer maximizing category profits, the first-order conditions imply

$$\begin{aligned} \frac{\partial \Pi_t^R}{\partial p_{it}} = 0 \Rightarrow s_{it} + (p_{1t} - w_{1t} - m_0) & \left[ \frac{\partial s_{1t}}{\partial p_{it}} \right] \\ & + (p_{2t} - w_{2t} - m_0) \left[ \frac{\partial s_{2t}}{\partial p_{it}} \right] = 0, \\ i = 1, 2. \end{aligned} \quad (7)$$

Substituting the price derivatives from (4) and solving the first-order conditions give us the retail-pricing equation

$$\begin{aligned} \left( \begin{array}{c} p_{1t} \\ p_{2t} \end{array} \right) = \left( \begin{array}{c} w_{1t} \\ w_{2t} \end{array} \right) + & \left( \begin{array}{c} \frac{1}{\alpha_{1t}} + \frac{s_{1t}}{\alpha_{1t}s_{0t}} + \frac{s_{2t}}{\alpha_{2t}s_{0t}} \\ \frac{1}{\alpha_{2t}} + \frac{s_{1t}}{\alpha_{1t}s_{0t}} + \frac{s_{2t}}{\alpha_{2t}s_{0t}} \end{array} \right) + m_0. \\ \text{Retail price} \quad \text{Wholesale price} \quad \text{Retail margin} \end{aligned} \quad (8)$$

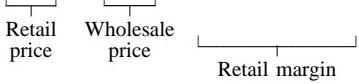
For brand-profit-maximizing case, the first-order conditions for the retailer are

$$\frac{\partial \Pi_t^R}{\partial p_{it}} = 0 \Rightarrow s_{it} + (p_{it} - w_{it}) \left[ \frac{\partial s_{1t}}{\partial p_{it}} \right] = 0, \quad i = 1, 2. \quad (9)$$

Substituting the price derivatives from (4) and solv-

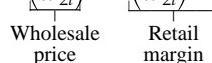
ing the first-order conditions give us the pricing equation

$$\left( \begin{array}{c} p_{1t} \\ p_{2t} \end{array} \right) = \left( \begin{array}{c} w_{1t} \\ w_{2t} \end{array} \right) + \left( \begin{array}{c} \frac{1}{\alpha_{1t}(1 - s_{1t})} \\ \frac{1}{\alpha_{2t}(1 - s_{2t})} \end{array} \right). \quad (10)$$



For the constant retailer margin model, the pricing equation is simply

$$\left( \begin{array}{c} p_{1t} \\ p_{2t} \end{array} \right) = \left( \begin{array}{c} w_{1t} \\ w_{2t} \end{array} \right) (1 + m) = \left( \begin{array}{c} w_{1t} \\ w_{2t} \end{array} \right) + \left( \begin{array}{c} m \\ m \end{array} \right). \quad (11)$$



In Pricing Equations (8), (10), and (11) the first term represents the input cost (wholesale price) to the retailer and the second term represents the retailer margin.

For the manufacturer Stackelberg model, the retailer's reactions to manufacturers' wholesaler prices are obtained by taking the derivatives of the retail prices in (8) and (10). It can be shown that (proof in Appendix) for the manufacturer Stackelberg model with the retailer maximizing category profits, the reactions are given by

$$\frac{\partial p_t}{\partial w_t} = \begin{pmatrix} \frac{\partial p_{1t}}{\partial w_{1t}} & \frac{\partial p_{2t}}{\partial w_{1t}} \\ \frac{\partial p_{1t}}{\partial w_{2t}} & \frac{\partial p_{2t}}{\partial w_{2t}} \end{pmatrix} = \begin{pmatrix} 1 - s_{1t} & -s_{1t} \\ -s_{2t} & 1 - s_{2t} \end{pmatrix}.^{10} \quad (12)$$

For the manufacturer Stackelberg model, with the retailer maximizing brand profits, the reactions are given by

<sup>10</sup>As we stated earlier, the logit demand model leads to vertical strategic substitutability (VSS) since  $\partial p_i / \partial w_i < 1$ .

$$\frac{\partial p_t}{\partial w_t} = \begin{pmatrix} \frac{(1 - s_{1t})^2(1 - s_{2t})}{(1 - s_{1t})(1 - s_{2t}) - (s_{1t}s_{2t})^2} & \frac{\alpha_{1t} (1 - s_{1t})^2(s_{1t}s_{2t})}{\alpha_{2t} (1 - s_{1t})(1 - s_{2t}) - (s_{1t}s_{2t})^2} \\ \frac{\alpha_{2t} (1 - s_{2t})^2(s_{1t}s_{2t})}{\alpha_{1t} (1 - s_{1t})(1 - s_{2t}) - (s_{1t}s_{2t})^2} & \frac{(1 - s_{2t})^2(1 - s_{1t})}{(1 - s_{1t})(1 - s_{2t}) - (s_{1t}s_{2t})^2} \end{pmatrix}. \quad (13)$$

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For the vertical Nash model, both the retailer and the manufacturers take their decisions simultaneously. Hence, only the direct effect of the change in wholesale price on retail price through the retailer input cost (wholesale price) is accounted for but not the indirect effect through its impact on the choice of retail margin. Hence, for both the category-profit-maximizing case and the brand-profit-maximizing case the impact on retail price for a change in wholesale price is given by

$$\frac{\partial p_t}{\partial w_t} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}. \quad (14)$$

For the constant margin model, the retailer reaction to a change in wholesale price is

$$\frac{\partial p_t}{\partial w_t} = \begin{pmatrix} \frac{\partial p_{1t}}{\partial w_{1t}} & \frac{\partial p_{2t}}{\partial w_{1t}} \\ \frac{\partial p_{1t}}{\partial w_{2t}} & \frac{\partial p_{2t}}{\partial w_{2t}} \end{pmatrix} = \begin{pmatrix} 1+m & 0 \\ 0 & 1+m \end{pmatrix}. \quad (15)$$

### Manufacturer Interactions

We now develop the model of manufacturer interactions (HSI) and the supply-side estimation equations. We allow for two alternative manufacturer interactions: (1) tacit collusion and (2) Bertrand competition.<sup>11</sup> The objective function of manufacturer  $i$  selling brand  $i$  in period  $t$  is given by

$$\Pi_{it}^M = (w_{it} - c_{it})s_{it}M_t + \theta(w_{jt} - c_{jt})s_{it}M_t - F_{it},$$

$$i = 1, 2; \quad j \neq i, \quad (16)$$

where  $w_{it}$  is the wholesale price for brand  $i$  that the manufacturer charges the retailer and  $c_{it}$  is the margin cost of brand  $i$ .  $F_{it}$  is the fixed cost to the manufacturer (it can include costs that are not related to the marginal sales of the brand; e.g., slotting allowances). Note that  $\theta = 1$  for the case of tacit collusion and  $\theta = 0$  for the case of Bertrand competition. We define the marginal cost of brand  $i$  as  $c_{it} = \gamma_i + \omega_{it}$ , where  $\gamma_i$  is the brand-specific margin cost, and  $\omega_{it}$  is the

<sup>11</sup>After choosing the best-fitting model using Vuong's (1989) test for these two extreme cases, we also estimate the CVs later. For the CV estimates, refer to the section "Implications of the Identification Problem."

brand-specific unobservable marginal cost at time  $t$ . Note that  $\omega_{it}$  is unobservable to the researcher, but observable to the manufacturers.

The first-order conditions for the manufacturer are given by

$$\begin{aligned} \frac{\partial \Pi_{it}^M}{\partial w_{it}} &= s_{it} + (w_{it} - c_{it}) \left[ \frac{\partial s_{it}}{\partial p_{1t}} \frac{\partial p_{1t}}{\partial w_{it}} + \frac{\partial s_{it}}{\partial p_{2t}} \frac{\partial p_{2t}}{\partial w_{it}} \right] \\ &\quad + \theta(w_{jt} - c_{jt}) \left[ \frac{\partial s_{jt}}{\partial p_{1t}} \frac{\partial p_{1t}}{\partial w_{it}} + \frac{\partial s_{jt}}{\partial p_{2t}} \frac{\partial p_{2t}}{\partial w_{it}} \right] = 0, \\ &\quad i = 1, 2; \quad j \neq i, \\ s_t + \left[ \left( \frac{\partial p_t}{\partial w_t} \frac{\partial s_t}{\partial p_t} \right) \cdot * \Theta \right] (w_t - c_t) &= 0, \end{aligned} \quad (17)$$

where

$$\Theta = \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$$

for tacit collusion and

$$\Theta = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$

for Bertrand competition. The  $\cdot *$  operator denotes element-by-element multiplication of a matrix.

We can thus solve for the wholesale prices as

$$w_t = c_t + \left[ \left( -\frac{\partial p_t}{\partial w_t} \frac{\partial s_t}{\partial p_t} \right) \cdot * \Theta \right]^{-1} s_t, \quad (18)$$

where the term

$$\left[ \left( -\frac{\partial p_t}{\partial w_t} \frac{\partial s_t}{\partial p_t} \right) \cdot * \Theta \right]^{-1} s_t$$

is the vector of margins that manufacturers choose for their brands.

Note that Equation (18) is purely in terms of observable data and model parameters that we will estimate. In the absence of data on wholesale prices, we can substitute out the expression for wholesale prices in (18) into the Retail-Pricing Equation (8), (10), and (11) to get the appropriate supply-side estimation equation that accounts for manufacturer and retailer behavior,

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**Table 2 Retail Margins**

Model	Retailer Margin
Manufacturer Stackelberg Category profit maximization	$\begin{pmatrix} \frac{1}{\alpha_{1t}} + \frac{s_{1t}}{\alpha_{1t}s_0} + \frac{s_{2t}}{\alpha_{2t}s_{0t}} \\ \frac{1}{\alpha_{2t}} + \frac{s_{1t}}{\alpha_{1t}s_{0t}} + \frac{s_{2t}}{\alpha_{2t}s_{0t}} \end{pmatrix} + m_0$
Manufacturer Stackelberg Brand profit maximization	$\begin{pmatrix} \frac{1}{\alpha_{1t}(1-s_{1t})} \\ \frac{1}{\alpha_{2t}(1-s_{2t})} \end{pmatrix}$
Vertical Nash Category profit maximization	$\begin{pmatrix} \frac{1}{\alpha_{1t}} + \frac{s_{1t}}{\alpha_{1t}s_{0t}} + \frac{s_{2t}}{\alpha_{2t}s_{0t}} \\ \frac{1}{\alpha_{2t}} + \frac{s_{1t}}{\alpha_{1t}s_{0t}} + \frac{s_{2t}}{\alpha_{2t}s_{0t}} \end{pmatrix} + m_0$
Vertical Nash Brand profit maximization	$\begin{pmatrix} \frac{1}{\alpha_{1t}(1-s_{1t})} \\ \frac{1}{\alpha_{2t}(1-s_{2t})} \end{pmatrix}$
Constant margin retailer	$\begin{pmatrix} w_{1t} \\ w_{2t} \end{pmatrix} m$

$$p_t = \underbrace{c_t}_{\text{Manufacturer cost}} + \underbrace{\left[ \left( -\frac{\partial p_t}{\partial w_t} \frac{\partial s_t}{\partial p_t} \right) * \Theta \right]^{-1} s_t}_{\text{Wholesale Margin}} + \underbrace{r_t}_{\text{Retail margin}}. \quad (19)$$

The actual estimation equations for the five models can be obtained by appropriately substituting into the above model the expression of  $r_t$  and  $\partial p_t / \partial w_t$ . We summarize these in Table 2 and Table 3, respectively, for quick reference. Because these expressions are in terms of observed market shares, which include the demand-side econometric error, we have incorporated demand-side econometric errors into the supply-side estimation equations in a manner consistent with the theoretical structure of the model. This is a key difference with respect to Cotterill and Putsis (2001), who use deterministic demand models in deriving their supply-side estimation equations, and therefore do not model the structural effects of demand-side econometric error in their supply-side model.

Specifically, denoting the  $i, j$  element of matrices  $\partial p_t / \partial w_t$ ,  $\partial s_t / \partial p_t$ , and  $\Theta$  as  $p_{w_{ijt}}$ ,  $s_{p_{ijt}}$ , and  $\theta_{ij}$ , we can write the two pricing-estimation equations by doing the appropriate matrix algebra as follows:

**Table 3 Retailer Reactions**

Model	Retailer Reaction $\left( \frac{\partial p_t}{\partial W_t} \right)$
Manufacturer Stackelberg Category profit maximization	$\begin{pmatrix} 1-s_{1t} & -s_{1t} \\ -s_{2t} & 1-s_{2t} \end{pmatrix}$
Manufacturer Stackelberg Brand profit maximization	$\begin{pmatrix} \frac{(1-s_{1t})^2(1-s_{2t})}{(1-s_{1t})(1-s_{2t})-(s_{1t}s_{2t})^2} & \frac{\alpha_{1t}(1-s_{1t})^2(s_{1t}s_{2t})}{\alpha_{2t}(1-s_{1t})(1-s_{2t})-(s_{1t}s_{2t})^2} \\ \frac{\alpha_{2t}(1-s_{2t})^2(s_{1t}s_{2t})}{\alpha_{1t}(1-s_{1t})(1-s_{2t})-(s_{1t}s_{2t})^2} & \frac{(1-s_{2t})^2(1-s_{1t})}{(1-s_{1t})(1-s_{2t})-(s_{1t}s_{2t})^2} \end{pmatrix}$
Vertical Nash Category profit maximization	$\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$
Vertical Nash Brand profit maximization	$\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$
Constant margin retailer	$\begin{pmatrix} 1+m & 0 \\ 0 & 1+m \end{pmatrix}$

$$\begin{aligned}
 p_{1t} &= \gamma_1 + \{[\theta_{12}s_{2t}(pw_{11t}sp_{12t} + pw_{12t}sp_{22t}) \\
 &\quad - \theta_{22}s_{1t}(pw_{21t}sp_{12t} + pw_{22t}sp_{22t})]/Det_t\} \\
 &\quad + r_{1t} + \omega_{1t}, \\
 p_{2t} &= \gamma_2 + \{[\theta_{21}s_{1t}(pw_{22t}sp_{21t} + pw_{21t}sp_{11t}) \\
 &\quad - \theta_{11}s_{2t}(pw_{12t}sp_{21t} + pw_{11t}sp_{11t})]/Det_t\} \\
 &\quad + r_{2t} + \omega_{2t},
 \end{aligned}$$

where

$$\begin{aligned}
 Det_t &= \theta_{11}\theta_{22}(pw_{11t}sp_{11t} + pw_{12t}sp_{21t}) \\
 &\quad \times (pw_{21t}sp_{12t} + pw_{22t}sp_{22t}) \\
 &\quad - \theta_{12}\theta_{21}(pw_{11t}sp_{12t} + pw_{12t}sp_{22t}) \\
 &\quad \times (pw_{21t}sp_{11t} + pw_{22t}sp_{22t}). \quad (20)
 \end{aligned}$$

Therefore, our estimation equations for the logit model are the demand equations in (3) and the pricing equations in (20). Note, however, that in the category-profit-maximization case the quantity  $m_0$  in retailer margin cannot be separately identified from the cost intercept ( $\gamma_i$ ). Hence, the intercept estimate in the pricing equation in the category-profit-maximization model is the sum of the brand-specific cost and the per-unit profit from the outside good.

**Equivalence of the Constant-Margin Retailer Model and Retailer Coordination Model.** In this section we demonstrate that the constant-margin retailer model that measures HSI using the CV approach (that has been used in previous studies) is econometrically identical to an alternative model that ignores manufacturers and just measures the degree of coordination in pricing across brands by the retailer using the CV approach. To do this, we first show that the margin parameter ( $m$ ) in the estimation equation for the constant-margin retailer is not identified, and

we therefore derive the actual estimation equation that is fit on the data. Then we derive the estimation equation for the retailer coordination model and show that the two equations are equivalent.

Substituting the retailer reaction to wholesale prices for the constant-margin model in Equation (15), the estimation equation becomes

$$p_t = \left\{ c_t + \frac{1}{1+m} \left[ \left( -\Theta \frac{\partial s_t}{\partial p_t} \right) \cdot * I \right]^{-1} s_t \right\} (1+m).$$

Hence,

$$p_t = c_t (1+m) \left[ \left( -\Theta \frac{\partial s_t}{\partial p_t} \right) \cdot * I \right]^{-1} s_t. \quad (21)$$

Therefore, the final estimation equation in this case is

$$p_t = \gamma_0 + \omega_t + \left[ \left( -\Theta_t \frac{\partial s_t}{\partial p_t} \right) \cdot * I \right]^{-1} s_t, \quad (22)$$

where  $\gamma' = \gamma(1+m)$  and  $\omega'_t = \omega_t(1+m)$ . Of course,  $m$  cannot be identified from this estimation equation. This estimation equation generalizes the equation derived in Vilcassim et al. (1999) for their linear demand model to a nonlinear demand model.

We now show that the supply-side estimation equation for a model measuring the degree of coordination in pricing across brands using the CV approach is econometrically identical to (22). Here we parameterize the level of coordination in retail pricing across brands.

The objective function of a retailer maximizing profits from brand  $i$  in period  $t$  is given by

$$\Pi_{it}^R = (p_{it} - w_{it})s_{it}M_t, \quad i = 1, 2. \quad (23)$$

The first-order conditions are given by

$$\begin{aligned}
 \frac{\partial \Pi_{it}^R}{\partial p_{it}} &= 0 \Rightarrow s_{it} + (p_{it} - w_{it}) \left[ \frac{\partial s_{it}}{\partial p_{it}} + \frac{\partial s_{it}}{\partial p_{jt}} \frac{\partial p_{jt}}{\partial p_{it}} \right] = 0, \\
 i &= 1, 2; \quad j \neq i.
 \end{aligned}$$

Denoting  $\theta_{21} = \partial p_{1t}/\partial p_{2t}$  and  $\theta_{12} = \partial p_{2t}/\partial p_{1t}$  for all  $t$ , we can write the above equation in matrix form as

$$s_t + \left[ \left( \Theta \frac{\partial s_t}{\partial p_t} \right) \cdot * I \right] (p_t - w_t) = 0, \quad (24)$$

where

$$\Theta = \begin{pmatrix} 1 & \theta_{12} \\ \theta_{21} & 1 \end{pmatrix}$$

and the  $\cdot*$  operator denotes element-by-element multiplication of a matrix and  $I$  is the identity matrix. We can interpret the  $\theta_{ij}$  terms as the measure of coordination in pricing across brands by the retailer. Therefore,

$$p_t = w_t + \left[ \left( -\Theta \frac{\partial s_t}{\partial p_t} \right) \cdot* I \right]^{-1} s_t. \quad (25)$$

If we express  $w_t$  in terms of factor prices and an error term, then the estimation Equation (25) is econometrically identical to (22). Hence, the ambiguity about what the estimates of the  $\theta$ s mean, i.e., whether they measure the extent of retail-pricing coordination or the degree of cooperation among manufacturers when retailers are nonstrategic and charge a constant margin.

### 3. Empirical Analysis

#### Data

We do our analysis on the yogurt and peanut butter categories on two EDLP stores from two different regional chains in a suburban market.<sup>12</sup> These stores happen to be the two largest in this market. The data are for a period of 104 weeks during 1991–1993. In the yogurt market, we analyze competition between the two largest brands, Dannon® and Yoplait. Together, they constitute about 82% of sales in this category in this market. In the peanut butter market, we analyze competition between the two largest brands in the market: Skippy® and Jif.® Together they constitute about 66% of sales in this category. The next largest national brand has less than 10% of market share in both categories in these stores. Private labels have a very small market share in these stores.

Because store-level data do not provide any information on the share of the “no purchase” alternative,

<sup>12</sup>These stores claimed to be EDLP. We verified these claims by comparing the variance of prices between these self-professed EDLP chains and self-professed high-low chains in this market. As expected, the price variance in the EDLP chains is about half of that of high-low chains. Furthermore, consistent with Bell and Lattin (1998), EDLP chains had a lower average price than the high-low chains.

we follow BGJ in using information from the household-level data to compute the share of “no purchase.” Assuming that the panel is representative of the universe of consumers, BGJ take the share of “no purchase” as the proportion of store visits by the pan-elists in the data that did not lead to a purchase in the category.<sup>13</sup>

#### Estimation

Our estimation equations are the demand equations in (3) and the pricing equations in (20). As discussed earlier, details such as consumer promotions and advertising are not available in scanner data and are unobserved by the researcher and therefore captured by the demand error terms  $\xi_{it}$ . However, manufacturers, retailers, and consumers have information on these, and therefore they affect the manufacturer’s and retailer’s choice of prices and the consumer’s decision to buy. Villas-Boas and Winer (1999) and BGJ offer evidence that this is indeed true. We do the same variation of the Hausman (1978) test that BGJ use and find price is endogenous. We use lagged price as an instrument in conducting this test.

Because features and displays are also strategic decisions made by the retailer, theoretically they should be considered endogenous. Putsis and Dhar (1999) found that features and displays are indeed endogenous. We test for endogeneity of features and display in two ways. First we follow Villas-Boas and Winer (1999) and look at the correlation between estimated residuals (using both three-stage least square (3SLS) and full-information maximum likelihood (FIML), where only price was treated as endogenous and feature and display were treated as exogenous) and feature and display. The correlations were not significant ( $p$  values  $> .2$ ), indicating that there would be no endogeneity bias if feature and display were treated as exogenous. One may note that in our demand model, we allow for interaction effects between price and feature and between price and display. This in-

<sup>13</sup>Because multiple purchases in a store visit are fairly common in the yogurt category, in this category we also reweight store visits by the number of purchases made during the visit in computing the “no purchase” share. The results, however, are not very sensitive to the reweighting.

teraction variable was crucial in eliminating the endogeneity bias problem.<sup>14</sup> The second test we do is a variation of the Hausman test. We estimate two models with price treated as endogenous using 3SLS: (i) with feature and display as endogenous and using instruments (lagged feature and display) and (ii) with feature and display as exogenous. If feature and display were indeed exogenous, then both models would be consistent, but the first model's estimates would have a higher variance because it is an instrumental variable method. However if feature and display were endogenous, only the first model would be consistent. If  $q$  denotes the vector of parameters to be estimated, then the test statistic  $(\hat{q}_1 - \hat{q}_2)'(\hat{V}_1 - \hat{V}_2)^{-1}(\hat{q}_1 - \hat{q}_2)$ , where  $\hat{V}$  is the estimated covariance matrix, is distributed as  $\Psi^2(\#q)$  distribution, where  $\#q$  is the number of parameters in the vector  $q$ . We find that the null hypothesis of exogeneity cannot be rejected ( $p = .17$ ).

This endogeneity of prices, however, implies that we still need to use an instrumental variables estimation procedure. Furthermore, errors across the supply and estimation equations are correlated due to price. We therefore need to use a simultaneous equation instrumental variables estimation procedure such as FIML or 3SLS. The major advantage of FIML estimation is that we do not need to provide instruments for prices, because the optimal instruments are generated within the estimation procedure. To compute the optimal instruments in FIML, however, we need to make the normal distribution assumption on the error terms. That is, we assume that  $\xi_{1t}, \xi_{2t}, \omega_{1t}, \omega_{2t}$  are assumed multivariate normal. In 3SLS there is no need to make the multivariate normal assumption, but we need to provide instruments. We prefer FIML in this paper, because formal tests for nonnested models (Vuong 1989) are available using likelihood estimates.

<sup>14</sup>We briefly explain the intuition for why modeling the interaction can help in eliminating the endogeneity bias problem. Let  $y_1 = x_1\beta_1 + x_2\beta_2 + x_1x_2\beta_3 + \epsilon$  be the true model. Suppose  $x_1$  is endogenous, but  $x_2$  is not. Instrumenting  $x_1$  will eliminate the endogeneity bias, but suppose we only fit the model  $y_1 = x_1\beta_1 + x_2\beta_2 + \epsilon_1$ , then  $\epsilon_1 = \epsilon + x_1x_2\beta_3$ . In this case we will find that  $\text{cov}(\epsilon_1, x_1) \neq 0$  and  $\text{cov}(\epsilon_1, x_2) \neq 0$ . Therefore, it will seem that both variables are endogenous if we do not include the interaction term.

However, to check whether our results are robust to the choice of estimation procedure, we also estimated the model using nonlinear 3SLS, using lagged prices as instruments for prices. The results that we report are consistent with both types of estimation procedures. We, however, report only FIML-based estimates, because we use these to do our tests of model selection.

## Results

**Model Selection: Choice of Functional Form.** We formally test whether the difference in log-likelihoods significantly favors one model using the Vuong's (1989) test of model selection for nonnested models. The best-fitting multiplicative model in the yogurt category had a log-likelihood of  $-343.09$  for Store 1 and  $-423.9$  for Store 2. For the peanut butter category, the best-fitting multiplicative model had a log-likelihood of  $-320.14$  for Store 1 and  $-421.39$  for Store 2. Clearly, the logit demand model performed much better in terms of fit compared with the multiplicative demand model. This is especially true considering that there were three extra parameters in the multiplicative model compared with the logit model. We performed the Vuong's test for this case, and reject the multiplicative model at  $p < 0.001$ . It therefore appears that VSS implication of the logit model fits the data better than VSC implication of the multiplicative demand model.

However, an alternative explanation for the poorer fit of the multiplicative model could be that it also fits the demand equations rather poorly, compared with the logit model. We therefore estimated only the demand models using both functional forms using 3SLS.<sup>15</sup> The logit model had a higher sum of squared errors than the multiplicative model, indicating that the multiplicative model with a greater number of parameters fits the data better if we use purely the demand equations. Hence, the reduction in fit when we include the pricing equations can be attributed to the explanation that the supply-side implications of the logit model (VSS) fit the data better than the supply-side implications of the multiplicative model (VSC).

<sup>15</sup>Note that we cannot use FIML if we do not have the same number of endogenous parameters and equations.

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**Table 4 Model Likelihoods and the Vuong Test Statistics**

Manufacturer Interaction	Retailer Objective/Manufacturer-Retailer Interaction	Likelihoods for Yogurt (Vuong Test Statistic)		Likelihoods for Peanut Butter (Vuong Test Statistic)	
		Store 1	Store 2	Store 1	Store 2
Tacit collusion	Category profit maximization	-196.90	-247.27	-240.66	-212.96
	Manufacturer Stackelberg	(—)	(—)	(—)	(—)
	Category profit maximization	-205.19	-298.29	-289.24	-265.47
	Vertical Nash	(2.259)	(2.101)	(2.734)	(2.132)
	Brand profit maximization	-202.38	-292.19	-259.44	-257.41
	Manufacturer Stackelberg	(2.028)	(1.972)	(1.700)	(1.961)
	Brand profit maximization	-208.25	-321.17	-288.82	-275.28
	Vertical Nash	(2.643)	(2.529)	(2.722)	(2.322)
	Constant margin	-207.29	-309.35	-297.95	-280.95
	Manufacturer Stackelberg	(2.529)	(2.318)	(2.969)	(2.426)
Bertrand competition	Category profit maximization	-203.66	-249.9	-271.11	-269.08
	Manufacturer Stackelberg	(2.040)	(2.030)	(2.164)	(2.204)
	Category profit maximization	-208.25	-309.35	-288.82	-275.28
	Vertical Nash	(2.643)	(2.318)	(2.722)	(2.322)
	Brand profit maximization	-266.78	-318.84	-266.78	-277.74
	Manufacturer Stackelberg	(6.558)	(2.489)	(2.005)	(2.368)
	Brand profit maximization	-204.39	-310.93	-291.55	-301.75
	Vertical Nash	(2.147)	(2.347)	(2.798)	(2.772)
	Constant margin	-211.03	-325.85	-303.71	-307.85
	Manufacturer Stackelberg	(2.949)	(2.608)	(3.114)	(3.821)

*Note:* The Vuong test statistic is with respect to the best-fitting model (with the highest log-likelihood).

The VSS implication that retail passthrough is less than 100% appears to be intuitive for the two categories that we analyze, since yogurt or peanut butter are not usually used as loss-leaders to drive store traffic. This implication is particularly valid for this data set, because our earlier analysis revealed that yogurt and peanut butter prices had a very limited impact on competitors' sales. Hence, these categories are unlikely to have been used to build store traffic.

**Model Selection: Results for the Logit Model.** The likelihoods for the different models of the yogurt and peanut butter markets for the logit functional form are reported in Table 4. Based on the log-likelihoods it seems obvious that, for both stores, the manufacturer Stackelberg model where manufacturers are involved in tacit collusion and the retailer maximizes category profits fits best in both categories. The Vuong statistics for the different models are computed with respect to this best-fitting model. Since the Vuong statistic is distributed as a standard normal,

the critical value for rejecting a model at a *p* value of 0.05 is 1.645. Given that all of the Vuong statistics are greater than 1.645, we can reject the other models in favor of the best-fitting model.

**Retailer Objective.** The stores that we analyze were part of large regional chains. Category management was becoming an increasingly popular concept at the beginning of the 1990s. In a survey of retailers, McLaughlin and Hawkes (1994) found that many large retailers that had the technological infrastructure to collect and analyze data had adopted the category management concept. Hence the result that retailer-maximized category profits has face validity. Our results also support the assumption widely made in the theoretical literature that retailers maximize category profits (Choi 1991, Lee and Staelin 1997).

**Manufacturer-Retailer Interaction (VSI).** The result that the manufacturer Stackelberg model best fits the data is consistent with the institutional practice

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**Table 5a Estimates for Best-Fitting Model in Yogurt Category**

	Store 1			Store 2		
	Parameter	SE	t	Parameter	SE	t
Intercept (Dannon®)	2.740	0.563	4.870	4.539	0.495	9.180
Intercept (Yoplait)	2.920	0.473	6.170	4.616	0.617	7.490
Feature	2.580	0.939	2.750	2.479	0.349	7.110
Display	2.122	2.227	0.950	4.078	1.783	2.290
Feature*Price	-4.378	1.356	-3.230	-3.883	0.639	-6.080
Display*Price	-0.800	3.447	-0.230	-6.507	3.445	-1.890
Price	-6.364	0.633	-10.060	-7.669	0.678	-11.310
Marginal cost (Dannon®) + outside good retail margin	0.337	0.042	8.100	0.281	0.050	5.620
Marginal cost (Yoplait) + outside good retail margin	0.457	0.045	10.250	0.428	0.053	8.060

**Table 5b Estimates for Best-Fitting Model in Peanut Butter Category**

	Store 1			Store 2		
	Parameter	SE	t	Parameter	SE	t
Intercept (Skippy®)	10.414	1.538	6.770	9.504	2.162	4.400
Intercept (Jif®)	10.523	1.528	6.890	9.616	2.142	4.490
Feature	3.470	4.303	0.810	8.807	2.376	3.710
Display	14.400	2.327	6.190	5.023	2.970	1.690
Feature*Price	-4.942	4.985	-0.990	-8.066	2.221	-3.630
Display*Price	-12.544	2.284	-5.490	-2.944	2.895	-1.020
Price	-10.539	1.326	-7.950	-9.049	1.831	-4.940
Marginal cost (Skippy®) + outside good retail margin	0.718	0.054	13.220	0.798	0.082	9.760
Marginal cost (Jif®) + outside good retail margin	0.714	0.056	12.870	0.771	0.086	9.020

in which manufacturers announce their wholesale prices and the retailers choose their retail prices as a response to these wholesale prices (Quelch and Farris 1983). This sequential approach has also been used in theoretical models of manufacturer-retailer pricing interactions (McGuire and Staelin 1983, Agrawal 1996).

Some theoretical research (e.g., Choi 1991) has put forth the argument that leadership in the manufacturer-retailer interaction may be a result of power balance between manufacturers and retailers. Using this argument, BGJ argue that vertical Nash is an appropriate assumption because increasingly there is balance of power between manufacturers and retailers. Our result that manufacturer Stackelberg leadership

may be a reflection of the fact that the balance of power in these categories is in favor of manufacturers. Given the dominance of the two leading brands in these categories, our result also has substantial face validity on the basis of the power argument. In an interview by Manning et al. (1998), one executive says it tellingly: "We can't walk away from the kind of shares that they have in some of the categories, so we have to work with them and we can't afford not to promote these products."<sup>16</sup>

<sup>16</sup>The author notes that Lee and Staelin (1997) show that Stackelberg leadership leads to greater profitability (and therefore implies greater power) only in the case of demand models characterized by VSS. The power balance argument the author makes holds only because

**Manufacturer-Manufacturer Interaction (HSI).** A cooperative outcome (relative to Bertrand competition) can be achieved in a noncooperative game by using appropriate punishment strategies when firms deviate from cooperative behavior. Such cooperative behavior is easier to sustain under certain market conditions than others. Besanko et al. (1996) provide an excellent discussion on how such coordination can be achieved in a noncooperative setting. A highly concentrated market facilitates cooperative behavior. This is because coordination is easier among a small number of firms. Further, detection of deviations from cooperative behavior is relatively easy, making the threat of punishment strategies more credible, thus enforcing cooperation. Because Dannon® and Yoplait have a high concentration in the yogurt market (82% in our data), it is not surprising that these firms behave cooperatively relative to Bertrand competition. The same arguments hold for Skippy® and Jif®, who collectively have over 66% market share in the stores that we analyzed.

**Demand and Cost Estimates for the Best-Fitting Model.** We report the results of our estimation for the best-fitting models in the yogurt and peanut butter category in Table 5a and 5b (see p. 258), respectively. All of the coefficients have the expected signs, giving the analysis substantial face validity.

As expected, features and display have a positive effect on sales in both categories and stores. Price has a negative effect on sales. In the final estimations we did not estimate brand-specific price coefficients, because it turned out in the estimation that they were not significantly different from each other when we incorporate the price-feature and price-display interaction effects. It is well known that a decrease in price when accompanied by a feature or display has a greater impact on sales than their separate effects. This was confirmed in that the interaction terms between price and display and between price and feature are negative and significant.

The demand intercept for Yoplait is marginally

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he has inferred that the VSS logit model is more appropriate than the VSC multiplicative model. We thank a reviewer for suggesting that we highlight this.

higher than for Dannon®. However, the estimate of manufacturing cost plus retailer margin from outside good for Dannon® is about 30% lower than that of Yoplait. This implies that Dannon® is the low-cost leader.<sup>17</sup> These results are similar to those of BGJ, even though our estimates are on a very different data set. However, the differences in the estimates of manufacturing cost plus retailer margin from the outside good indicates that Store 1 gets a greater margin from the outside good in the yogurt category.

In the case of the peanut butter category, the demand intercept for Skippy® is marginally lower than for Jif®. The estimate of manufacturing cost plus retailer margin from outside good for Skippy® is marginally lower than that of Jif®. However, the differences in the estimates of manufacturing cost plus retailer margin from the outside good indicate that Store 2 gets a greater margin from the outside good in the peanut butter category.

We report estimates of elasticities for the two categories in Table 6a and 6b. Across both stores, we find that Yoplait has greater price elasticity than Dannon®. Further, Yoplait has greater cross-elasticity with respect to Dannon®'s prices than vice versa. This indicates a very strong market position for Dannon®, and it is not surprising when we consider that Dannon® is usually regarded as "synonymous with yogurt."<sup>18</sup> In the peanut butter category, across both stores, Skippy® has greater price elasticity than Jif®. Further, Skippy® has greater cross-elasticity with respect to Jif®'s prices than vice versa. This indicates a stronger market position for Jif® than for Skippy®. Our results in the peanut butter market are consistent

<sup>17</sup>According to the teaching case YoplaitUSA in the marketing text by Berkowitz et al. (1999, p. 607), some serious concerns for YoplaitUSA in 1993 (the period of our analysis) were "(i) Retail Prices: Yoplait's prices for a six ounce cup was higher on some lines than competitor's eight ounce cups. For example, the prices on Yoplait's 4 pack are about 20% higher per cup than Dannon®'s and Kraft's 6 pack. (ii) Low gross margins: Margins have declined, at least partly because of high production and overhead costs." The concern about the relatively high production costs and its impact on prices give face validity to our estimates.

<sup>18</sup>"General Mills Inc.: Yoplait Custard Style Yogurt (A)," Harvard Business School Case 9-586-087, 1986.

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**Table 6a Elasticity Estimates for Yogurt Category**

	Store 1		Store 2	
	Elasticity of Dannon®	Elasticity of Yoplait	Elasticity of Dannon®	Elasticity of Yoplait
w.r.t. Dannon® price	-4.293	0.640	-4.601	1.289
w.r.t. Yoplait price	0.286	-5.420	0.537	-6.462

**Table 6b Elasticity Estimates for Peanut Butter Category**

	Store 1		Store 2	
	Elasticity of Skippy®	Elasticity of Jif®	Elasticity of Skippy®	Elasticity of Jif®
w.r.t. Skippy® price	-11.026	2.328	-8.755	2.118
w.r.t. Jif® price	2.488	-10.505	2.583	-8.370

with the strength of these brands at the national level (Deveney 1993).

**Implications of the Identification Problem.** We have shown that the constant-margin retailer model is econometrically identical to a model measuring the degree of retail coordination. Hence, intuitively we should expect that CVs estimated for the HSI might be exaggerated under the assumption of a constant-margin retailer compared with CV estimates when the retailer strategically maximized category profits with the manufacturer as the Stackelberg leader. We test this intuition by comparing the CV estimates for the two models.<sup>19</sup> The CV estimates for the two models in both categories and stores are reported in Table 7. CV estimates are consistently higher, exaggerating the degree of cooperation among manufacturers for the constant-margin retailer model. This is consistent with the intuition we gain from the analytical results. The empirical result further underscores the need to properly model the VSI in inferring the HSI.

## 4. Conclusion

In this paper, we empirically inferred the VSI between manufacturers and retailers and the HSI be-

<sup>19</sup>Since FIML does not converge for the CV models, we use 3SLS for estimation.

**Table 7 CV Estimates for the Logit Model: Category-Profit-Maximizing Retailer and Constant-Margin Retailer**

	Yogurt		Peanut Butter		
	Store 1	Store 2	Store 1	Store 2	
Category profit maximizing retailer	$\theta_1$	0.122	0.126	0.151	0.147
	$\theta_2$	0.154	0.149	0.399	0.316
Constant margin retailer	$\theta_1$	0.232	0.262	0.297	0.204
	$\theta_2$	0.252	0.232	0.454	0.693

tween manufacturers simultaneously. The approach is particularly appealing because it can be used in the common situation in which the wholesale price information of all competitors is not available. We showed analytically that the simplifying assumption that a retailer charges a constant margin (used in earlier research) may misinterpret category management behavior by the retailer to be cooperative behavior by manufacturers. Consistent with the intuition from the analytical result, we find that the estimated cooperation among manufacturers is exaggerated for the constant-margin model, highlighting the need to simultaneously model and infer the VSI when analyzing the HSI.

Since packaged goods manufacturers spend a sizable share of their marketing-mix budget on trade promotions (Bucklin and Gupta 1999), several decision support systems (DSSs) have been developed to aid manufacturers in their promotion planning (e.g., Neslin et al. 1995, Tellis and Zufryden 1995, Midgley et al. 1997, Silva-Risso et al. 1999). Our results are of substantive import in guiding the assumptions that go into such DSSs. For example,

1. DSSs usually assume Bertrand behavior among manufacturers (e.g., Midgley et al. 1997). By explicitly testing for Bertrand behavior as well as cooperative behavior among manufacturers, we found that manufacturers in these markets tend to be more cooperative. A DSS that assumes Bertrand pricing behavior would have led to more aggressive pricing than would be warranted by the actual behavior of the market participants.
2. Many DSSs assume manufacturer Stackelberg behavior between manufacturers and retailers (e.g.,

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Tellis and Zufryden 1995). However, the theoretical literature does not provide clear guidance on whether such an assumption is appropriate; it shows that a change in assumption can have substantive implications for pricing behavior of the channel member. Given the apparent shift in power to retailers, this question becomes even more important to managers. We found that for the categories and markets that we analyzed, the manufacturer Stackelberg assumption is appropriate.

3. DSSs have used different assumptions about retailer-pricing rules. Silva-Risso et al. (1999) assume that retailers follow a simple passthrough rule and manufacturers incorporate that assumption when deciding their trade deal. Tellis and Zufryden (1995) assume that the retailer's objective is to maximize category profits. By testing both these specific assumptions, we found that both retailers' objective is to maximize category profits.

4. DSSs also make assumptions about the functional form of demand. While functional forms of demand have been evaluated in terms of the fit of the model to sales data, its ability to accommodate the behavioral implications of the supply side have not been evaluated. We found that the logit model performed better than the multiplicative model in its ability to accommodate the strategic behavior of firms for the categories that we analyze.

We now discuss some of the limitations in this paper and possible avenues for future research. First, it would be useful to validate the methodology by checking how well the model predicts actual wholesale prices by estimating the model on a data set with wholesale prices. Second, the current estimation method assumes that the estimation equations can be derived in closed form. To allow for greater flexibility in the functional forms and also to extend the analysis to a larger number of brands, we need to enable estimation even when closed-form estimation equations cannot be obtained.

Clearly more research in other categories at other retail stores is needed before we can develop a body of evidence that will enable us to understand the impact of supply characteristics (for example, degree of concentration in market, manufacturer-retailer power

balance, availability of private labels) and demand characteristics of category (e.g., high inertia or variety seeking, stockpiling, average price sensitivity, loss leader) on the inference of strategic interactions. For example, Cotterill and Putsis (2001) find that the Vertical Strategic Interactions are different across categories, while we found manufacturer Stackelberg behavior in both categories we analyze. Understanding the determinants of these differences should be of interest in future work.

Putsis and Dhar (1998) have also done a cross-category analysis of how competitive behavior between private labels and manufacturers changes as a function of the category and market characteristics. Sudhir (2001) develops hypotheses combining arguments from game-theoretic research and the ability-motivation paradigm (Boulding and Staelin 1995) about how competitive behavior in different segments of the auto market will differ, depending on the demand-and-supply characteristics of these markets, and then tests these hypotheses. Such an analysis will help provide deeper insights into the determinants of horizontal and vertical strategic interactions and appropriateness of functional forms of demand.

The issue of retail competition was not found to be particularly important in the yogurt and peanut butter categories. Future research into categories such as detergents and soda, which are known to have an impact on store traffic, is needed to study the role of strategic retail competition on retailer-pricing behavior. Also, retail competition may be at the basket level across a number of categories (Bell and Lattin 1998).

We have limited ourselves to the inference of manufacturer-retailer interaction only when the retailer is EDLP. However, accounting for unobserved heterogeneity among consumers in the demand model can enable us to investigate how loyalty and switching behavior, asymmetric responses to lower-price-tier brands, etc., may cause high-low pricing behavior. We are investigating how to use household-level data to infer heterogeneity distributions and how to incorporate this information into the aggregate model so that we can extend our analysis to the case of high-low retailers. Horsky and Nelson (1992) and Gold-

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berg (1995) provide good starting points for this stream of research. Recently, there has been interest in recovering heterogeneity from aggregate data (Berry et al. 1995, Kim 1995, Nevo 2001, Sudhir 2001, Chintagunta 1999). In recent work, Villas-Boas and Zhao (2000) address many of the issues in modeling channel behavior with household-level data.

We have not modeled any kind of dynamics that affect demand or supply. Forward buying by consumers, habit persistence, variety seeking, advertising wearout, etc., can have intertemporal demand effects, which in turn can affect supply-side behavior. Forward buying by retailers is another supply-side intertemporal effect. While the use of efficient consumer response (ECR) has significantly reduced forward buying on the part of retailers, it is still a significant component of how a retailer reacts to a trade deal. This is an important issue for future research. For a more comprehensive set of methodological and substantive questions that await research in this area, we direct the reader to Kadiyali et al. (2001).

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### Appendix

#### Reactions for Category-Managing Retailer

Taking the derivatives of the retail prices in Equation (8) of the paper,

$$\begin{aligned} \frac{\partial p_{1t}}{\partial w_{1t}} = 1 + \frac{1}{s_{0t}^2} & \left[ s_{0t} \left( \frac{1}{\alpha_{1t}} \left( \frac{\partial s_{1t}}{\partial p_{1t}} \frac{\partial p_{1t}}{\partial w_{1t}} + \frac{\partial s_{1t}}{\partial p_{2t}} \frac{\partial p_{2t}}{\partial w_{1t}} \right) \right. \right. \\ & + \frac{1}{\alpha_{2t}} \left( \frac{\partial s_{1t}}{\partial p_{1t}} \frac{\partial p_{1t}}{\partial w_{1t}} + \frac{\partial s_{1t}}{\partial p_{2t}} \frac{\partial p_{2t}}{\partial w_{1t}} \right) \left. \right) \\ & + \left( \frac{s_{1t}}{\alpha_{1t}} + \frac{s_{2t}}{\alpha_{2t}} \right) \left( \frac{\partial s_{1t}}{\partial p_{1t}} \frac{\partial p_{1t}}{\partial w_{1t}} + \frac{\partial s_{1t}}{\partial p_{2t}} \frac{\partial p_{2t}}{\partial w_{1t}} + \frac{\partial s_{2t}}{\partial p_{1t}} \frac{\partial p_{1t}}{\partial w_{1t}} \right. \\ & \left. \left. + \frac{\partial s_{2t}}{\partial p_{2t}} \frac{\partial p_{2t}}{\partial w_{1t}} \right) \right]. \end{aligned}$$

Substituting the share derivatives with respect to prices from Equation (4), we get

$$\frac{\partial p_{1t}}{\partial w_{1t}} = 1 - \frac{s_{1t}}{(1 - s_{1t} - s_{2t})} \frac{\partial p_{1t}}{\partial w_{1t}} - \frac{s_{2t}}{(1 - s_{1t} - s_{2t})} \frac{\partial p_{2t}}{\partial w_{1t}}. \quad (\text{A1})$$

Similarly,

$$\frac{\partial p_{2t}}{\partial w_{1t}} = -\frac{s_{1t}}{(1 - s_{1t} - s_{2t})} \frac{\partial p_{1t}}{\partial w_{1t}} - \frac{s_{2t}}{(1 - s_{1t} - s_{2t})} \frac{\partial p_{2t}}{\partial w_{1t}}. \quad (\text{A2})$$

Solving (A1) and (A2) for  $\partial p_{1t}/\partial w_{1t}$  and  $\partial p_{2t}/\partial w_{1t}$ , we have  $\partial p_{1t}/\partial w_{1t} = 1 - s_{1t}$  and  $\partial p_{2t}/\partial w_{1t} = -s_{1t}$ . By symmetry,  $\partial p_{2t}/\partial w_{2t} = 1 - s_{2t}$  and  $\partial p_{1t}/\partial w_{2t} = -s_{2t}$ .

These reactions are summarized in Equation (12) of the paper.

#### Reactions for Brand-Managing Retailer

Taking the derivatives of the retail prices in Equation (10) of the paper,

$$\begin{aligned} \frac{\partial p_{1t}}{\partial w_{1t}} = 1 + \frac{1}{\alpha_{1t}^2(1 - s_{1t})^2} & \left[ \alpha_{1t} \left( \frac{\partial s_{1t}}{\partial p_{1t}} \frac{\partial p_{1t}}{\partial w_{1t}} + \frac{\partial s_{1t}}{\partial p_{2t}} \frac{\partial p_{2t}}{\partial w_{1t}} \right) \right], \\ \frac{\partial p_{2t}}{\partial w_{1t}} = \frac{1}{\alpha_{2t}^2(1 - s_{2t})^2} & \left[ \alpha_{2t} \left( \frac{\partial s_{2t}}{\partial p_{1t}} \frac{\partial p_{1t}}{\partial w_{1t}} + \frac{\partial s_{2t}}{\partial p_{2t}} \frac{\partial p_{2t}}{\partial w_{1t}} \right) \right]. \end{aligned}$$

Substituting the share derivatives with respect to prices from Equation (5), we get

$$\frac{\partial p_{1t}}{\partial w_{1t}} = 1 - \frac{s_{1t}}{(1 - s_{1t})} \frac{\partial p_{1t}}{\partial w_{1t}} - \frac{\alpha_{2t}}{\alpha_{1t}} \frac{s_{1t}s_{2t}}{(1 - s_{1t})^2} \frac{\partial p_{2t}}{\partial w_{1t}}, \quad (\text{A3})$$

$$\frac{\partial p_{2t}}{\partial w_{1t}} = \frac{\alpha_{1t}}{\alpha_{2t}} \frac{s_{1t}s_{2t}}{(1 - s_{2t})^2} \frac{\partial p_{1t}}{\partial w_{1t}} - \frac{s_{2t}}{(1 - s_{2t})} \frac{\partial p_{2t}}{\partial w_{1t}}. \quad (\text{A4})$$

Solving (A3) and (A4) for  $\partial p_{1t}/\partial w_{1t}$  and  $\partial p_{2t}/\partial w_{1t}$ , we have

$$\frac{\partial p_{1t}}{\partial w_{1t}} = \frac{(1 - s_{1t})^2(1 - s_{2t})}{(1 - s_{1t})(1 - s_{2t}) - (s_{1t}s_{2t})^2} \text{ and}$$

$$\frac{\partial p_{2t}}{\partial w_{1t}} = \frac{\alpha_{1t}}{\alpha_{2t}} \frac{(1 - s_{1t})^2(s_{1t}s_{2t})}{(1 - s_{1t})(1 - s_{2t}) - (s_{1t}s_{2t})^2}.$$

By symmetry,

$$\frac{\partial p_{2t}}{\partial w_{2t}} = \frac{(1 - s_{2t})^2(1 - s_{1t})}{(1 - s_{1t})(1 - s_{2t}) - (s_{1t}s_{2t})^2} \text{ and}$$

$$\frac{\partial p_{1t}}{\partial w_{2t}} = \frac{\alpha_{2t}}{\alpha_{1t}} \frac{(1 - s_{2t})^2(s_{1t}s_{2t})}{(1 - s_{1t})(1 - s_{2t}) - (s_{1t}s_{2t})^2}.$$

These reactions are summarized in Equation (13) of the paper.

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